Water Quality Monitoring Program for the Cumberland Piedmont Network

Late Summer, 2002

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Introduction

During the summer of 2001 Mammoth Cave National Park Hydrogeologist Joe Meiman traveled to the parks of the Cumberland Piedmont Network (CPN) to perform hydrogeologic assessments relative to water resources. The main objective was to provide information to the CPN Board of Directors, Technical Committees and potentially to a water-resources specialist relevant to drafting an effective, efficient and sound water quality monitoring program. Information included: description of water resources; description of past, current, and potential sampling sites; examination of past and present water resources inventories, monitoring activities, and research; examination of water quality data records; identification of data-gaps; and general recommendations of sampling strategies.

Prior to parks visits the NPS Water Resources Division (WRD) provided a database from a search of STORET (USEPA). WRD Data Manager Dean Tucker returned an MSAccess database of over 358,000 individual water quality records for the CPN parks (sans SHIL as their data had not been uploaded onto the new STORET platform at the time of this report). A record is any individual parametric entry from a specific sampling location at a particular time. For example, a record may represent the result of a Cadmium analysis on August 14, 1997 at Long Branch at the US68 bridge, or simply the water temperature of Big Spring on December 2, 1972. At first the presence of over 358,000 records may give one the impression of a vast amount of water quality data representing our parks. Upon further review this is a false impression. When the STORET database is queried, a larger geographic area than the park is chosen in order to be certain that all park samples included. This process yields much data that were collected in the general area around the park as well as data collected within the park. For example, at CHCH we find that while there are 463 individual sample locations listed, only 69 refer to “Chickamauga” within the location field, with only three sites located on West Chickamauga Creek (which forms the units southern boundary) and no locations within the park itself. This is not to say that review of the STORET database is not without merit, but rather there is far less applicable water quality data that is first apparent.

In addition, each park unit was compared against the USEPA list of 303d waterbodies in order to determine if impaired waters exist. The only USEPA 303d waters in the CPN parks was West Fork Stones River (Stones River National Battlefield). In addition, special listings of state waters within the park (Outstanding Resource Waters, Wild and Scenic Rivers, etc) was be compiled.

The remainder of this document is the hydrogeologic assessment of each park in the CPN, led by a general discussion of possible monitoring strategies and program direction.

General Discussion and Conceptual Plan

The CPN WQ Monitoring Program must keep the following points in focus if it is to be successful:

1.) A "One Size Fits All" approach to monitoring water resources within the CPN is not advised. It becomes readily apparent that not all water resources within the CPN are equal, either in specific park mission (Enabling Legislation) or in resource significance and use. In some parks, water resources may be the primary focus of why the park exists (LIRI), in others, while not being a main attraction, water resources may include rare, threatened or endangered biota (SHIL), and yet water resources in some parks may be considered nearly ancillary (GUCO).
2.) It must be a "monitoring program" and not a "research program". This is for two basic reasons, foremost that the NRC program calls for the long-term monitoring of park resources. The program must be designed to track long-term trends on a specific list of relevant parameters rather than focusing upon a few cause and effect relationships. That is not to say that specific research is not needed. A main problem is that basic, fundamental water quality data – which is a precursor to research – simply does not exist in most CPN units.
3.) The WQ monitoring program must address long-term park resource management goals. Each park must be able to articulate, either by its own personnel or with consultation with water resource professionals, specific park goals for its water resources. This aspect is of extreme importance. There is little use in attaining or maintaining water resource quality goals that are not commensurate with park management objectives. Park objectives establish "designated uses" for water resources and thus set the parameter lists and water quality standards for each park unit.
4.) The WQ program must focus on park waters. Although many parks may receive flow from beyond park boundaries, unless real external threats to park waters are identified, we must first focus on park waters. If external waters need to be sampled, the NPS may cooperate with state agencies for monitoring. If the park must sample externally, long-term agreements with property owners must be made to assure long-term monitoring.
5.) The WQ monitoring program must be well coordinated with all other natural resources monitoring efforts. Although the WQ program will be drafted and executed to a stand-alone level, if it is to truly function as a component of vital signs monitoring, it must be fully integrated with all other aspects of the CPN NRC Program.

Germane to the first point listed above, "all aquatic resources are not equal". If key elements are examined, such as aquatic life, human use, significance to the park, and park management objectives, water resources can be evaluated and ranked accordingly. Parks with highly significant water resources (central to park mission, supporting important biological communities (Federal Threatened or Endangered species, or State Listed), or heavily used recreational waters) are ranked higher than parks with less significant waters (not to say that any waters are insignificant).

Each state, as required by the USEPA, have developed water quality standards and protocols for defining designated uses of water resources. Some CPN park waters may have already been designated by a state. For example, the Green River within MACA has been designated by the Commonwealth of Kentucky as an Outstanding Resource Water. This designation comes with specific water quality standards. Other designated uses may be as simple as primary contact recreation, which has its own standards. Most CPN water resources most likely are not yet classified. This must be done by the CPN Technical Committee or at a CPN Workshop meeting. For example, if not otherwise designated, a cave stream at RUCA with limited secondary contact recreation and supporting a cave-adapted aquatic community and a mean annual temperature of 13^o C may be designated as a "cold-water aquatic habitat" and thus follow regulations of the State of Alabama for cold-water aquatic habitats. Furthermore, the NPS can impose higher standards than required by the state. These rankings, which can be thought of as park-based designated use classifications, are also used to choose water quality standards and targets.

The main body of this report will describe the water resources of each park of the CPN. The following paragraphs serve a summary of relative rankings and a presentation of a conceptual plan of the CPN Water Quality Monitoring Program.

Knowledge of aquatic resources with respect to water quality of the CPN runs the full spectrum. Long-term water quality monitoring efforts have been underway at LIRI since the early 1990's. Other parks, such as CUGA, CARL, and KIMO have built, over the past several decades, a core of water quality data that will serve as an excellent foundation for long-term efforts. The majority of parks have a very limited – both in terms of frequency and parameters – water quality record, and still others (CHCH and RUCA) are proverbial "black boxes" where the absolute fundamental element of water resource management, the watersheds are not defined.

Due to this wide range of knowledge, especially in parks where little is known, a general water quality inventory must be conducted during the first years of this program. This inventory will follow all protocols of the monitoring program – in accordance to USGS NWQA program. Adherence to the NWQA standards will serve two main goals: generation of high-quality, defendable data, and comparison of the CPN water quality data to the NWQA database as a whole.

Central to the program will be non-conditional synoptic sampling, where samples are taken, regardless of flow and weather conditions, on fixed calendar dates. Basic fixed sampling locations will be at integrator sites (locations commonly at tributary confluences or springs which are representative of water quality issues of individual sub-basins) and indicator sites (locations downstream from either suspected or documented water quality threats and pristine conditions). It is recognized that in order to best fit with other CPN monitoring activities some flexibility in site selection is likely. This strategy, over the long-term, has proven to yield statistically valid data used to track long-term trends in water quality.

Water Resource Ranking

Parks are ranked in accordance to water resource significance. Although in light of additional data and park management objectives these rankings may indeed change prior to the final draft of the WQ program, such alterations must be based entirely upon resource and management merit.

Category One – Water resources are central to park establishment or mission. High amount of recreational use activities. Contains Federally or State Listed Threatened, Endangered or Rare aquatic or dependent species. Know exceedences of key water quality standards or 303d listed waters. High probability of water resource damage with little or no information of fundamental elements of hydrogeology or water quality.
CHCH, CUGA, LIRI, RUCA, SHIL, STRI

Category Two – Water resources, although important with respect to general interpretation or aesthetics, not central to park establishment or mission, with limited or no recreational use. Contains no Federally or State Listed Threatened, Endangered or Rare aquatic or dependent species.
ABLI, CARL, KIMO

Category Three – Water resources not central or perhaps even mentioned in park establishment or mission. No recreational use. Contains no Federally or State Listed Threatened, Endangered or Rare aquatic or dependent species. In general, water resources are ancillary in nature and management.
COWP, GUCO, FODO, NISI

Monitoring Parameters

Most NRC networks will be limited to basic field parameters in their water quality monitoring due to the high cost of laboratory analysis. The CPN will have a much greater range of analytical parameters, as it will use the MACA LTEM Water Laboratory. This lab is near completion at the beginning of FY02. QA/QC protocols, compliant to USEPA laboratory certification standards, will be drafted and in place by October 2002. Although each park may not require the full suite of possible parameters during the long-term monitoring phase, all available parameters will be included during the inventory phase. The MACA LTEM lab will be able to perform the following analysis:

Bacteria (Fecal coliform; MFC)
Turbidity (nephelometer)
Anions (fluoride, chloride, nitrite, bromide, nitrate, phosphate, sulfate; IC)
Cations (lithium, sodium, ammonium, potassium, magnesium, calcium; IC)
Transition metals ($iron^{+3}$, lead, copper, cadmium, manganese, cobalt, zinc, nickel, IC)
Pesticides (atrazine; IC)
Chlorophyll A (scanning spectrofluorophotometer)
Suspended solids
Total Organic Carbon-Total Inorganic Carbon (Carbon Analyzer)

Field analysis will be performed at time of sample collection. Four sets of field probes and meters have been purchased (FY01) and are ready for use. Field analysis will include:

pH
Dissolved Oxygen
Temperature
Specific Conductance
Discharge
ANC (acid neutralization capacity)
Bacteria (see above)

As a final note to this preamble, I would like to thank the many people who either assisted me in the field or the office. These include: Stacy Allen (SHIL), Larry Bean (RUCA), Mary Belue (LIRI), Toby Clarke (LIRI), Dennis Curry (CHCH), Jack Grubaugh (University of Memphis), Jimmy Johnson (CUGA), Jim Lewis (STRI), Teresa Leibfreid (CPN), Chris Revels (KIMO), Pat Ruff (COWP), Jim Szyjkowski (CHCH), Gary Talley (ABLI), Dean Tucker (WRD), Robert Wallace (FODO), Steve Ware (GUCO), Waren Webber (CARL), and Eric Williams (NISI).

Hydrogeologic Assessment of the parks of the Cumberland Piedmont Network

The following park assessments follows a format that describes the general hydrogeology of the park, past work, water quality threats, human uses and aquatic biological findings, and potential sampling locations. These general categories are based, at least in the early stage of the program, on data and assumption. If water quality data exist and show water quality degradation, then the site is considered "degraded". If there are no or little data and adjacent, upstream land uses indicate a strong potential for water quality degradation, the site is considered "potentially degraded". If data indicate, or we can reasonably assume base on adjacent, upstream land use, that water quality is unimpaired, the site is considered "pristine". If reasonable assumptions cannot be made – if a karst watershed is undefined for example – the site is considered "potentially degraded".

Park	**Pristine**	**Potentially Degraded**	**Degraded**
FODO	1	1	
SHIL	5	3	
STRI		2	4
CHCH	1	6	
LIRI	1	11	2
RUCA		3	
CARL	2	2	
NISI	1	2	
COWP	3	1	
KIMO	3		2
GUCO		1	1
ABLI	1		1
CUGA	4	7	1
TOTAL	**22**	**39**	**11**

Fort Donelson National Battlefield *(July 16-17, 2001)*

Hydrogeology

Ft. Donelson is situated upon Mississippian carbonate strata common to the Pennyrile Plateau of the Illinois Basin – the same rock that contains the world's longest know cave (Mammoth Cave). Karst development, although present, is somewhat limited and masked by a thick deposit of unconsolidated fluvial material of the ancient Cumberland and Tennessee Rivers. This material, typically up to 10 meters thick, is comprised to a large extent of rounded to semi-rounded cherts and river gravels. These deposits can be viewed in erosional cuts of unnamed seasonal tributaries of the Hickman Creek Embayment.

Most surface channels within the park are seasonal, flowing only after sufficient rainfalls. The seasonality is due to the limited catchment areas of these streams, and possibly due to flow lost through the fluvial deposits into the underlying limestones. There is one perennial spring within the park, Hickman Spring (a very small spring along the River Circle Trail Loop).

Bounded by impounded water of Lake Barkley on three sides, Ft. Donelson appears to be rich in aquatic resources. However, the park boundary stops just short the impoundment of the Cumberland River at Lake Barkley, Hickman Creek and Indian Creek. Only in times of extreme high water does this water flood into the park. There are only two perennial streams within Ft. Donelson: Hickman Spring and Indian Creek upstream of the inundated portion of the creek.

Past Inventories/Monitoring/Research Activities

As with many culturally-focused small parks, little work has been done with regards to water quality monitoring. The US Army Corps of Engineers have collected sporadic water quality data within Lake Barkley adjacent to the park over the years, but none within the park. The SERO funded the collection and analysis of three rounds of grab samples in November 1998, January and May 1999. Sampling locations in this inventory included: Indian Creek east of Grave's Battery, East side of Indian Creek Bay; Lake Barkley (Cumberland River) at overlook, South side of Hickman Creek Bay; and Hickman Spring. Data collected during this study are found in Appendix A.

Associated Land Uses and Water Quality Threats

The watershed of Fort Donelson (with the possible exception of karst groundwater influence and small, seasonal drainages) lies outside park boundaries. These lands are generally comprised of woodlands, light agricultural, residential, and transportation (US 79). Indian Creek is the main drainage entering the park and is represented by all above land uses (with the exception of US 79, which crosses the extreme downstream section of Indian Creek near the embayment).

Human Use and Aquatic Biology

Although much primary (swimming) and secondary (fishing) contact recreation occurs within Lake Barkley, little, if any, recreational use occurs within the park. No aquatic biological inventory has been done.

Potential Water Quality Monitoring Locations

Indian Creek: East of Grave's Battery: This is the best location to monitor Indian Creek within the park. This location has been used for past monitoring efforts. Access is easy and safe in all conditions. Samples should be taken at the footbridge that crosses Indian Creek just east of Grave's Battery. <u>Potentially degraded site</u>

Hickman Spring: This very small spring is located along the River Circle Trail Loop. This location has been used for past monitoring efforts. Access is easy and safe in all conditions. Samples should be taken at the spring outlet near the footbridge on River Circle Trail Loop. <u>Pristine site</u>

All other perennial sampling locations are outside park boundaries. These locations – namely Hickman Bay (west side), Indian Creek Embayment (east side), and Lark Barkley (at overlook) – may be included at specific request of the park.

Park Water Resources Rank: Category 3.

Shiloh National Military Park *(July 17-19, 2001)*

Hydrogeology

Shiloh is situated upon Mississippian carbonate strata on the west bank of the Tennessee River. Karst development, although present and generally expressed by small perennial springs, is somewhat limited and masked by a thick deposit of unconsolidated fluvial material of the ancient Tennessee River. This material, typically up to 10 meters thick, is comprised to a large extent of rounded to semi-rounded cherts and river gravels. These deposits can be viewed in erosional cuts of streams draining the park and in gravel quarries to the north.

Largely hidden by the rolling woodlands and fields, the park is dissected by three main perennial streams; Dill Branch, Shiloh Creek, and Tilghman Branch. There are at least two limestone springs (Rea and Shiloh) within the park. With the exception of Owl Creek, which borders the northwestern edge of the park, the watersheds of Shiloh's streams are contained within the park.

It is interesting that current water quality data show that the waters of Shiloh are extremely low in dissolved ions (Appendix A). Park waters, even limestone springs, are characterized by low specific conductances, low calcium, magnesium, and bicarbonates, and are moderately alkaline. These streams and springs rely on bank stores within adjacent and overlying fluvial deposits to maintain base flow through the drier months. The resultant chemistry makes these waters very susceptible to acidification, as there is little buffering capacity.

Past Inventories/Monitoring/Research Activities

As of the time of this writing (Autumn of 2001) Shiloh's water quality data had not been entered into STORET. An emphasis on water resources began in the 1990's and continues today.

The NPS conducted a water quality and biological community study between May 1994 and March 1995. Five water quality stations were established for 13 monthly sampling rounds. In addition, five biological sites were chosen and sampled six times to track the distribution and diversity of benthic macroinvertebrates. Water quality parameters included field measures of pH, temperature, dissolved oxygen, specific conductivity, total dissolved solids, and turbidity. The report notes that low pH (ranging from 5.4 to 7.4) may be natural (a result of decomposition of leaf material) or anthropogenic (atmospheric deposition from a nearby pulpmill). Although not noted in the report, these waters tend to have a very low buffering capacity and are, by nature, highly susceptible to acidification, regardless of the source of acid. Biological integrity (based upon the Izaak Walton League of America's Stream Quality Survey) ranged from poor to excellent.

Between 1995 and 1998 the University of Memphis was contracted to perform an inventory of fish, reptiles, and amphibians. . The aquatic inventory revealed 50 species of fish and 27 species of amphibians. The University of Memphis was contracted in 1999 to perform a two-year study that includes: biological community monitoring, stream morphology measurements (physical characteristics), and water quality monitoring. Biological community monitoring is performed seasonally is focused on invertebrates and will produce and index of biological integrity. Annual assessments of stream's physical characteristics include: epifaunal substrate/available cover, pool substrate characterization, pool variability, sediment deposition, channel flow status, channel alteration, channel sinuosity, bank stability, vegetative protection, and riparian vegetative zone width. Monthly water quality measurements include wetted depth, discharge, water temperature, dissolved oxygen, specific conductivity, pH, hardness, ortho-phosphates, total nitrates, and turbidity.

Associated Land Uses and Water Quality Threats

The watersheds of Shiloh (with the exception of Owl Creek) lie within park boundaries. These lands are generally comprised of the woodlands and managed light agricultural of the Battlefield's cultural landscape. Owl Creek separates the park from intensely row-cropped land as it flows across a broad floodplain to the Tennessee River. Owl Creek has experienced hydrologic and riparian alteration over the years. Many of the adjacent agricultural lands have been tiled, drained, and channelized, resulting in the deposition of sediments on park lands (see "Inspection Report, Owl Creek Bottomlands at Shiloh Military Park, 21 March 1978" for details).

Human Use and Aquatic Biology

No recreational activities occur in the small streams of Shiloh. It should be noted, although park management should be consulted as to their management objectives, that a portion of the park's eastern border is inundated by Kentucky Lake (Tennessee River). At the time of the establishment of Shiloh National Military Park, its border was apparently the edge of the Tennessee River. With the damming of the Tennessee its border is now underwater. The question to pose to park management is: Is this portion of the park actively managed as part of the park or is it considered part of the lake/river? If the latter is true, then this portion of the lake/river receives both primary and secondary contact recreation.

The University of Memphis (1998) was contracted by the NPS to perform an ichthyological inventory of Shiloh. 50 species of small fish (representing 10 orders, 14 families, and 35 genera) were identified – only one of which (yellow perch) was non-native. No endemic, rare, threatened, or endangered species were found. However, 21 of the 50 species represent new distribution records for the state of Tennessee. This inventory found the lake chubsucker that had previously been found in only eight locations in Tennessee. This fish is considered very uncommon and was thought to have been extirpated from most of its original range due to agricultural practices. This study concludes that although no endemic, rare, threatened, or endangered species were found, the streams of Shiloh are abundantly biologically diverse and have intact ecosystems.

In a related study (University of Memphis, 1999) amphibians and reptiles were inventoried. This work, in combination of previous surveys, identified 27 species of amphibians and 25 species of reptiles. Only one state-listed specie was found (mole salamander) and six species of amphibians were found which are outside their documented geographical range.

Potential Water Quality Monitoring Locations

Note: when conducting field activities in Shiloh field personnel should be wary of poisonous snakes (namely water moccasins) and yellow jackets.

Lower Dill Branch: Located near the mouth of Dill Branch, just upstream of Brown's Landing Road. This location is used by the current University of Memphis water quality study. Back-flooding from river is possible. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

Upper Dill Branch: This site is located in the headwaters of Dill Branch at the confluence of two unnamed tributaries. This location is used by the current University of Memphis water quality study. Access is easy and safe in all conditions. <u>Pristine site</u>

Shiloh Spring: Located just south of Shiloh Church and east of Corinth Road. Little is known about this small, perennial limestone spring. It is a tributary of Shiloh Creek and has not been sampled in past or current monitoring efforts. A cursory test during this field visit showed a specific conductance of 22.6 μS and a temperature of 16.8^o C. Access is easy and safe in all conditions. A previously non-inventoried salamander was found in this spring during the visit. <u>Pristine site</u>

Rea Spring: Located just north of Rea Springs Road. Little is known about this small, perennial limestone spring. It is a tributary of Shiloh Creek and has not been sampled in past or current monitoring efforts. A cursory test during this field visit showed a specific conductance of 20.3 μS and a temperature of 16.1^o C. Access is easy and safe in all conditions. <u>Pristine site</u>

Shiloh Creek: Located just upstream of the park boundary at the crossing of TN 22. This location is used by the current University of Memphis water quality study. Access is easy and safe in all conditions. <u>Pristine site</u>

Tilgham Branch: Located just upstream of the park boundary at the crossing of TN 22. This location is used by the current University of Memphis water quality study. Access is easy and safe in all conditions. <u>Pristine site</u>

Owl Creek: Forms the northwest border of the park and is accessed by the Hamberg-Savannah Road. This creek is not part of the current University of Memphis water quality study, but was included in both fish and amphibian inventories. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

Tennessee River (Kentucky Lake) at Pittsburg Landing: The original bounds of the park were marked by a low-water mark along the western bank of the Tennessee River. Currently, Kentucky Lake has elevated the water level onto previously sub-arealy exposed lands. In effect, the park boundary is well under water today. This reach of the lake/river may contain significant mussel populations and is met with a wide variety of water quality issues, including upstream pulp mills and proposed coal-fired power plants. <u>Potentially degraded site</u>

Park Water Resources Rank: Category 1.

Stones River National Battlefield *(July 20, 2001)*

Hydrogeology

Stones River National Battlefield is located almost entirely upon the karst of Ordovician limestones directly adjacent to the West Fork of Stones River. The underling karst is the primary reason for the lack of surface waters – with the exception of the West Fork, which is the area's master stream, within the park (that is, the karst aquifer under the park and surrounding area drains to the West Fork via solutional conduits and springs). In general the park consists of six separate parcels of land, the largest are the fields and woods near the Visitor Center. To the north lies the second largest tract at McFadden's Ford that contains a stretch of the West Fork.

The USGS identified five key water resources at Stones River in a 2000 proposal "Proposed Level 1 Water-Quality Inventories for Key Water Bodies at Stones River National Battlefield, Tennessee": 1.) West Fork Stones River at Redoubt Brannon (West College Street), 2.) Rebel Yell Cave, 3.) King Pond (near the Artillery Monument), 4.) McFadden Spring (Battlefield Spring), and 5.) West Fork Stones River at McFadden's Ford (Thompson Lane).

Past Inventories/Monitoring/Research Activities

Although the West Fork Stones River has been the target of scores of water samples since the 1960's, there does not appear to exist a comprehensive study (in terms of spatial distribution or temporal continuity) of water quality. It appears the both the state of Tennessee and the National Park Service has taken several samples in the West Fork as well as Lytle Creek (a major tributary of West Fork) just upstream of the park.

The USGS recently completed and one-year study (August 2000 through June 2001) to document water quality at the key sites listed above. Four quarterly samples were collected during this study which represents the first comprehensive inventory of the water quality of Stones River National Battlefield. Field measurements include dissolved oxygen, alkalinity, pH, temperature, specific conductivity, turbidity and fecal coliform. Laboratory analysis include the wide range of inorganics (major cations and anions) and organics that comprise a "Level 1" survey. Preliminary results indicate low water quality in several parameters. Dissolved oxygen were below criterion for fish and aquatic life (5.0 mg/l) at both West Fork sites in January 1001 and at King Pond in January and June 2001. Elevated levels of *Escherichia coli* were found in both West Fork sites. One sample exceeded the USEPA single-sample limit of 253 col/100 ml. Arsenic, cadmium, chromium, copper, lead, nickel, selenium, and thallium were detected in key water bodies but did not exceed fish and aquatic life criterion. Chloroform, tetrachloroethylene, trichloroethylene, and cis-1,2-dichloroethylene were also detected in all key waters except Rebel Yell Cave. Trichloroethylene concentrations at McFadden Spring (8.9 μg/l) and King Pond (32 μg/l) were found – both exceeded Tennessee State drinking water standards.

There has been several dye-tracing studies done in and around Stones River National Battlefield. In 1997 Dr. Albert Ogden (Middle Tennessee State University) completed dye-tracing showing that the Murfreesboro Old City Dump flowed to both Mulch Spring and Rebel Yell Cave.

Associated Land Uses and Water Quality Threats

The waters of Stones River National Battlefield may well represent the most threats of any park in the CPN. Basically situated downstream from the city of Murfreesboro, land use immediately upstream (and surrounding) the Battlefield is dominated by industrial and residential uses. The West Fork receives runoff from this large developed area, as well as the effluent of sewage treatment plants and seepage from landfills. The USGS (in the proposal cited above) stated that Rosebank Dump, a Tennessee Hazardous Substance Site, is located along the West Fork adjacent to the Redoubt Brannon portion of the park. The old Murfreesboro City Dump is located between the Redoubt Brannon and Fortress Rosecrans sections of the park. In addition to these known landfills, several illegal dumps were discovered during the construction of the Stones River Greenway that connects several portions of the park along the West Fork. The USGS has also suggested that old sewer lines and areas with inadequate septic tanks add to the bacterial and nutrient levels of the West Fork.

Human Use and Aquatic Biology

With the exception of a small cave stream in Rebel Yell Cave, a couple of small farm ponds near McFadden's Ford, and short spring runs (Battlefield Spring for example) the only water body large enough to support recreational activities is the West Fork Stones River. The NPS provides access to the West Fork at McFadden's Ford via a canoe launch. Considerable primary contact recreation occurs along the entire run of the West Fork as it parallels the Stones River Greenway. Secondary contact recreation through fishing also occurs all along this stretch of the river.

No complete inventory of the aquatic biology has been done at Stones River National Battlefield. When this inventory takes place special habitats such as spring runs and cave streams should be included.

Potential Water Quality Monitoring Locations

West Fork at McFadden's Ford: Located on West Fork Stones River, this site represents the focus of most aquatic recreation within the park. Public access is gained by a canoe launch along the Stones River Greenway. West Fork Stones River itself is listed by the State of Tennessee as a 303d water. Access is easy and safe in all conditions. This location is used by the current USGS water quality inventory. <u>Degraded site</u>

Battlefield Spring: This small limestone spring is located just downstream (north) of McFadden's Ford. The spring run has been rock-walled many years ago. At the time of the site visit the spring was discharging approximately 2 liters/minute into West Fork. Access is easy and safe in all conditions. This location is used by the current USGS water quality inventory. <u>Degraded site</u>

West Fork at Redoubt Brannon: Located on West Fork and upstream of McFadden's Ford, the river at Redoubt Brannon is just downstream of the confluence of Lytle Creek, a state 303d listed water (West Fork Stones River itself is listed by the State of Tennessee as a 303d water). Access is easy and safe in all conditions. This location is used by the current USGS water quality inventory. <u>Degraded site</u>

Mulch Spring: This very small spring (nearly a seep at the time of the site visit, discharging approximately 0.5 liters/minute into West Fork) is located directly behind Bragg's Headquarters. The USGS notes that dye tracing has connected this spring with the nearby Murfreesboro Old City Dump. Access is easy and safe in all conditions. This location is used by the current USGS water quality inventory. <u>Potentially degraded site</u>

Rebel Yell Cave: This site was not visited during the site visit (no on-hand park personnel knew of its exact location). Its approximate location is within the park along the historic McFadden's Lane. This small cave apparently contains a small seasonal stream that has been shown by dye tracing to receive flow from the Murfreesboro Old City Dump. Access is easy and safe in all conditions. This location is used by the current USGS water quality inventory. <u>Potentially degraded site</u>

King Pond near Artillery Monument: This small spring-fed farm pond is on the recently acquired land adjacent to (east of) Van Cleve Lane. At this time it is not know what the park's management objectives are regarding this pond, but it is included in the current USGS water quality inventory as it is downstream of a large industrial complex. Access is easy and safe in all conditions. <u>Degraded site</u>

Park Water Resources Rank: Category 1.

Chickamauga and Chattanooga National Military Park *(July 30-31, 2001)*

Hydrogeology

Chickamauga and Chattanooga National Military Park primarily consists of two large tracts of land – the Chickamauga Battlefield and the Lookout Mountain Battlefield and Point Park – in northern Georgia and southern Tennessee, respectively. Both units exhibit karst hydrogeology, however, little, if anything is known about their karst watersheds.

The Chickamauga Battlefield unit contains several small-order seasonal streams that, for the most, are headed from within the park. West Chickamauga Creek forms the southeast border of this unit. Although numerous water quality samples have been taken along this creek (both in the urban upstream and industrial downstream portions) no known samples have been taken within this bordering stretch. The broad valleys of the Chickamauga unit are underlain by Mississippian limestones that are buried by thick soils and fluvial deposits. A moderate, perennial spring, Cave Spring, is located in the southwestern portion of the unit near the Wilder Monument.

The major surface stream of the Lookout Mountain Battlefield and Point Park unit is Lookout Creek that forms a portion of the unit's western border. Surface waters on the mountain are limited to seasonal streams and spring runs. At the top of Lookout Mountain (an anticline gently plunging to the south-southwest) Pennsylvanian sandstones and conglomerates are exposed. The flanks of the mountain are underlain by the Bangor and Mounteagle Limestones (separated by the Hartsille Formation (sandstone). Small springs issue from near the top of this sequence (Jackson, Gum and Rock Springs) as larger springs (Skyuka Spring) are located near the elevation of the Tennessee River at the base of the mountain.

Similar to many mature karst settings, the surface hydrology of Lookout Mountain is characterized by the lack of surface streams, as all surface water is quickly captured by the underlying karst aquifer. A thick, extremely heterogeneous mantel of colluvium is common over broad areas of the carbonate strata, especially in the deeply entrenched ravines. Elsewhere, where overburden is not present, a well-developed, highly fractured epikarst (the solutionally modified limestone surface) is exposed. This pinnacled limestone surface is typified by deep solutionally-enlarged vertical fractures allowing the rapid recharge of surface waters or contaminants into the karst aquifer. Although limestone is not exposed at the surface in the mantled areas, it is quite reasonable to expect the carbonate surface to be similar to the adjacent subareal epikarst -- capable of capturing large volumes of surface waters through solutionally-enlarged fractures and bedding planes. Unlike the Mississippian karst terrains of Southcentral Kentucky, there is a relative absence of sinkholes on Lookout Mountain. Sinkholes tend to form along preferential flow vectors, such as fracture intersections. Due to the extremely high density of fractures in the limestones of Lookout Mountain, surface water has countless routes to exploit, and thus, sinkhole development is rare.

Past Inventories/Monitoring/Research Activities

With the exception of a survey of cave biology by Dr. Horton Hobbs (Whittenburg University) in the 1990's in which a few water quality samples were extracted, no studies have been done at Chickamauga and Chattanooga. In 1996 many water samples were collected in response to a large fuel-oil spill on the nose of Lookout Mountain. These samples, most of which were taken in Mystery Falls Cave (located just outside a small portion of park land on the northern edge of the mountain) and were targeted for petroleum hydrocarbons.

Associated Land Uses and Water Quality Threats

With the exception of West Chickamauga Creek, most surface waters within the Chickamauga Battlefield unit are headed within the park. The watershed of West Chickamauga Creek upstream of the park contain a variety of landuses, ranging from urban, light residential, woodland, agricultural, and industrial.

The Lookout Mountain Battlefield and Point Park unit water quality threats and land uses are unclear. While Lookout Creek's watershed is comprised of woodlands, agricultural, and light residential, land uses of the remainder of park watershed remains a mystery as the watersheds themselves are not defined. For the most part, the park wraps around the city of Lookout Mountain located atop the mountain. Water and pollutants run off the silisiclastic-capped mountain as surface streams until the underlying limestones are encountered, where they sink. These waters reappear on the flanks and near the base of the mountain in springs. Which springs may be affected by this community is unknown, as their watersheds have not been delineated.

Human Use and Aquatic Biology

No known primary-contact recreational activities occur within either unit of the park. Secondary-contact recreation does occur (fishing) within West Chickamauga and Lookout Creeks. Aquatic biological inventories have not been completed at either unit. Whittenburg University has preformed a cave biological inventory in several caves within the Lookout Mountain Battlefield Point Park Unit in 1992.

Potential Water Quality Monitoring Locations

West Chickamauga Creek: Located at Alexander's Bridge this site is the most downstream point of West Chickamauga Creek within the park. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

Cave Spring: Located a few hundred meters south-southwest of the Wilder Monument. The watershed of this moderate, perennial spring is unknown. Flow was approximately 10 l/s at time of visit. Access is easy and safe in all conditions. <u>Pristine site</u>

Jackson Spring: Located near the top of Lookout Mountain at the extreme southwestern portion of the Lookout Mountain Battlefield and Point Park unit. The watershed of this small, perennial spring is unknown. Flow was approximately 0.5 l/s at time of visit. Access is easy and safe in all conditions, except during times of heavy snow and ice. Potentially degraded site

Skyuka Spring: Located adjacent to Lookout Creek at the extreme southwestern portion of the park. This watershed of this large, perennial spring is unknown. Flow was approximately 15 l/s at time of visit. Access is moderately difficult and safe in all conditions, unless the sampler hikes from Ochs Gateway where heavy snow and ice may present a hazard. Potentially degraded site

Rock Spring: Located at base of upper bluff just west of Point Park. The watershed of this small, perennial spring is unknown. Flow was approximately 2 l/min at time of visit. Access is easy and safe in all conditions, except during times of heavy snow and ice. Potentially degraded site

Gum Spring: Located at about halfway down the west flank of Lookout Mountain (southwest of Point Park). The watershed of this small, perennial spring is unknown. Flow was approximately 3 l/min at time of visit. Access is moderately difficult and safe in all conditions, except during times of heavy snow and ice. Potentially degraded site

Lookout Creek: Forming the southwest border of the Lookout Mountain Battlefield and Point Park unit. This large, perennial stream can be accessed and sampled at various locations. Perhaps the best location to sample this creek is on park land adjacent to the Chattanooga Nature Center. Access is easy and safe in all conditions. Potentially degraded site

Park Water Resources Rank: Category 1.

Little River Canyon National Preserve *(August 1, 2001)*

Hydrogeology

Situated upon the axis of the southwestern-plunging anticline of Lookout Mountain, Little River carves a deep (200 meters in the lower end) canyon, ultimately emerging near from the end of the mountain at Mouth of Canyon Park. Little River Canyon National Preserve consists of a narrow river corridor between Little River Falls and Mouth of Canyon Park (including approximately the lower three kilometers of its tributary Bear Creek). Above Little River Falls, park lands extend laterally protecting a wider portion of the riparian corridor, uplands, and portions of small tributary watersheds. The upstream end of the park abuts DeSoto State Park on the West Fork Little River.

The Preserve is in large park underlain by Pennsylvanian silisclatic strata, of which the many canyon bluffs are created. These thick beds of sandstones (and to a lesser extent, shales) give way to the underlying limestones near Mouth of Canyon Park. Although limestone is subarealy exposed in this lower section of the river, there are no known caves or significant springs.

The core resources of Little River Canyon National Preserve tie directly to the river, be they recreational opportunities on the river or hiking and climbing canyon bluffs, or the myriad of plant life that rim the canyon uplands. Of course, Little River itself and its aquatic communities serves and the primary resource.

Past Inventories/Monitoring/Research Activities

Perhaps no other unit within the CPN (with exception of possibly samples taken in CUGA during the construction of the Cumberland Gap Tunnel) has a more complete and rigorous record of water quality. Since the middle of 1998 Little River Canyon National Preserve Hydrologist Mary Belue has conducted a bi-weekly sampling program. Water quality parameters (including dissolved oxygen, pH, total dissolved solids, temperature, turbidity, reactive phosphorous, free and total chlorines and fecal coliforms (*E.coli*) and enterococci). Until 2001 analysis was performed for nitrate, ammonia, and sulfate (these parameters were discontinued due to the generation of hazardous wastes during analysis). Currently the program monitors water quality at 15 stations.

Between November 1996 and October 1997, Jacksonville State University conducted a water quality baseline survey. Most of the sites used in this inventory are used currently in the park's monitoring program.

Associated Land Uses and Water Quality Threats

Like many “river parks”, Little River Canyon National Preserve primarily consists of the main stem of the river and a narrow corridor on either side. With the exception of a wider corridor between Little River Falls and DeSoto State Park, Little River Canyon National Preserve is bounded by the upper edge of the canyon. Thus development occurs, at an ever increasing rate, right up to the park boundary. Development is largely residential, and lured by the view of the canyon, occurs directly upon the boundary. There are no sewer lines along the canyon and residential waste water is treated by individual septic systems. A large residential development is underway near the Bear Creek/Canyonland Park area. The possibility for future development is very high, and it is not hard to imagine a time in the not-to-far-distant future where the entire canyon will be rimmed with houses.

Currently the most pressing water quality threats are located within the headwaters of East Fork Little River and lower river tributaries such as Johnnie’s Creek. Pollution sources are largely non-point from agricultural and silvicultural landuse.

Within the park’s watershed are several primary transportation routes. Alabama route 35 crosses Little River at the Falls and county routes 89 and 103 are within the West and East Forks, respectively. Little River Canyon Rim Parkway, as the name implies, hugs the western rim of the canyon from the Falls to Canyon Mouth Park.

Human Use and Aquatic Biology

Little River attracts a variety of both primary and secondary contact recreational activities. The river between Little River Falls and Mouth of Canyon park passes through series of highly technical white-water rapids and is primarily used by experienced paddlers. An occasional hiker may wade in the waters adjacent to one of two trails into the lower canyon; Powell and Eberhart. Casual wading and swimming activities occur with great numbers, however concentrated at Little River Falls and Mouth of Canyon Park.

Biological inventories of Little River, far from complete, include the following studies. In 1988 and 1989 (March through October each year) Kenneth S. Frazer, Steven C. Harris and G. Milton Ward of the University of Alabama at Tuscaloosa conducted an inventory of Tricoptera (published in 1991). A fifteen-month ichthyofaunal survey was done as a Master's thesis project by Terri L. Dobson from Jacksonville State University in 1992 (published in 1994). In 1997 a study of the ESA listed Kral's Water Plantain was conducted by Drs. Jerri Higginbotham and David Whetstone of Jacksonville State University.

Potential Water Quality Monitoring Locations

A special thanks to Mary Belue of Little River Canyon National Preserve for the following description of her active water quality monitoring sites. Although most sites listed are easily and safely accessed, field personnel must exercise caution when sampling any site under flood conditions, where even a relatively benign site under low to moderate flow may prove dangerous.

Canyon Mouth Park (34 17 21.72 N, 85 40 55.3 W): This site is located a short distance from where Little River exits the canyon and approximately five kilometers above its confluence with Weiss Lake. This sampling site is located on a riffle area between two pools that receive heavy use from swimmers. Just downstream from the site a real-time USGS flow gauging station. A hiking trail, pavilion, restrooms, and picnic tables and opportunities to swim and fish draw many people daily to this small stretch of river. Although the restrooms are recent and a new peat moss filtration septic system has been installed, pollution problems may still persist due to people not using the provided facilities. The site is easily accessed in all conditions. <u>Potentially degraded site</u>

Johnnie's Creek (34 17 50.64N, 85 42 08.46W): Johnnie's Creek is a major tributary located about one kilometer above the Canyon Mouth Park sample site. It flows from the west and drains a rather large watershed that contains numerous farms and continually increasing residential development. Samples are taken from below the County Road 275 bridge just above the falls. Here the creek is somewhat narrow with a substrate of broken bedrock (and beer bottles). This watershed contains numerous farms including bovine and equine, sheep, llamas, emus, chickens and pigs. High bacterial counts and nutrients are usually a problem here. In addition to agricultural use, silviculture practices and expanding residential developments also threaten water quality. Direct impact on-site is the abuse of patrons. Although privately owned, this particular site is used for recreation. No restrooms or trashcans exist therefore the area is highly littered and the stench of fecal matter is usually present. No means of control have been imposed and continued use and neglect will only further the degradation of the site. Access is easy and safe (with the exception of trash and menacing trespassers) in all conditions. <u>Degraded site</u>

Eberhart Point (34 21 00.62N, 85 40 21.34W): This sampling site is located on a riffle between two pools. The site is accessed by Eberhart trail and is located approximately 50 meters upstream from where the trail meets the river. Here the river is relatively narrow and the canyon walls tower nearly 121m (400ft) above. The substrate is composed of large cobble and boulders of various sizes. Eberhart trail is one of few trails that allow people to gain a "canyon experience"; however, the trail is rather steep, therefore this area of the river does not receive as much activity as more accessible sites. Although the limited number of people here may not pose an impact to the river, Bear Creek, another large tributary draining from the west, joins Little River only 300 meters above this sampling site. Its watershed contains many houses, new developments, and large expanses of agricultural land that could negatively impact water quality. Assess is difficult and special care should be used under icy and snowy conditions. <u>Potentially degraded site</u>

Highway 35 Bridge (34 23 44.37N, 85 37 37.07W): This site is located above Little River Falls, just upstream of the State Highway 35 bridge. The river here is broad and flows over large slabs of sandstone bedrock. Unlike the bouldery substrate found below the falls, here and all along much of the main stem above the falls, the channel is composed of flat, broken bedrock with rocky shoals in the shallow areas. This site, along with the Canyon Mouth Park, is the most popular area for sunbathing and swimming. In the summer, people lounge within the pools created by depressions in the sandstone bedrock. Restrooms were just recently added to this area, the installation of which should reduce any negative impacts on water quality, should the patrons oblige. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

Yellow Creek (34 24 11.15N, 85 38 12.6W): This site is located just above the falls and the county road 295 bridge. The sample site is located on the main stem of this fourth order stream just 1.3 kilometers before emptying into the west side of the Little River. This site is not a recreational area, nor does it lie within federal boundaries, however, due to the fact that, for the majority of the times, when measures are high at the Highway 35 bridge site, the source of the problem is traced back up to this creek. The watershed is a little over 3600 hectares and contains numerous homes, agricultural fields, cattle, horse and chicken farms, and several reclaimed coal strip mines. Access is easy and safe in all conditions. <u>Degraded site</u>

Burnt House Ford (HC) (34 25 00.01N, 85 35 56.99W): This site is located approximately 4.5 kilometers upstream from the highway 35 bridge site, on the main stem of the river. The site is easily accessible from an old road off the north end of park road 01. This area of river is bedrock and is just downstream from Hurricane Creek, a large tributary from the west that drains a large area of domestic and agricultural uses, such as is all other sites. The road leading to the site is gated, allowing only park staff to access the road. The only personnel accessing this road is a state game official who maintains wildlife food plots midways down the road. Some horseback riders ride around the gate and ride to this site along the river. Otherwise, no other activity takes place there, except for the wildlife. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

DeSoto State Park (34 29 41.49N, 85 36 57.1W): This site is located on the West Fork of Little River, below the picnic area southeast of the Country Store. The site is accessed by the Scout trail that leads across Indian Falls. This area of the river is somewhat narrow and the substrate is fragmented sandstone bedrock with interspersed boulders. Discharge data are collected by a USGS gauging station located approximately 20 meters upstream. This site receives abundant recreational use, being within meters of the Scout trail. Adequate facilities nearby help to reduce any impacts from unsanitary uses. Other potential threats include agriculture and septic systems of the many homes in the area. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

DeSoto Falls (34 32 55.33N, 85 35 25.09W): This site is located in the State Park area on the West Fork of Little River, outside of the federal boundary. The site is just below a concrete impoundment where the water flows over flat slabs of sandstone bedrock. This area of the State Park receives heavy, concentrated uses. Fishermen, swimmers, and boaters use the impoundment just above the collection site. Motorized boats are allowed upon this area of the river, whereas they are not permitted within the Preserve boundary.

Many homes, for both year-round and summer-use, line the edge of the lake and canyon area. There are restroom facilities available here for visitors but septic tanks of the many surrounding homes may pose possible threats to water quality. Access is easy and safe in all conditions. Potentially degraded site

Johnson Branch (34 38 15.73N, 85 30 25.06W): This creek is a tributary to the West Fork, within Walker County, Georgia. The site is located at a bridge where Griff-Johnson Road crosses the creek. Here the substrate is sand and cobble, and the creek is narrow and usually shallow. The area upstream contains two camps, domestic dwellings and current developments, agriculture, and silviculture. Access is easy and safe in all conditions. Potentially degraded site

Sulphur Springs (34 40 24.82N, 85 31 10.85W): This site is located at the northern most extent of the West Fork of Little River. These headwaters begin in Dade County, Georgia draining only a small portion of the upper reaches of the watershed. This portion of the watershed is still unfamiliar to park staff and new sites may be considered. For now, this site is accessed from a county road right-of-way above the culvert. This poses a problem when the grasses are allowed to grow high and snakes are commonly seen here. Besides snakes, access is easy and safe in all conditions. Pristine site

Middle Fork (34 32 17.45N, 85 31 40.74W): This is the only site on the Middle Fork of the Little River. The site is accessed under the bridge over state road 117 along state right-of-ways. This site is located downstream from current and proposed large subdivisions within Walker County, Georgia. Some agriculture occurs in the area, but domestic development is the biggest concern, especially within the watershed of the Middle Fork. Access to this site is a bit challenging and sometimes dangerous when the grass is allowed to grow up along the road shoulder and around the bridge abutments. Potentially degraded site

Lookout Mountain Camp (34 30 57.43N, 85 31 44.31W): The site is located just below the impoundment at a camp for boys. It is only operational May through August yet there are some year-round residents on site. The sample is taken with a grab sampler from the camp's swimming dock. The sample site is a long run with deep waters and the substrate is mostly slabs of sandstone bedrock and some cobble. The area at the dam, just upstream, receives heavy usage and with no restroom facilities or garbage cans, it is very trashy and unmaintained. This usage combined with excessive housing developments and faulty septic systems creates the potential for serious issues arising in this area. No problems are known to stem from the camp but their septic system should be routinely checked yet this is unknown to us if this is done. Access is easy and safe in all conditions. Potentially degraded site

East Fork (34 31 22.29N, 85 30 20.52W): This site is accessed from state road 117 below the bridge. It is a narrow part of the river with sand and bedrock substrate. This site is located in Chattooga County, Georgia. This site is important because of the many uses within this subwatershed. Domestic development, agriculture, clearcutting, and reclaimed strip mines are prevalent throughout the area. Access is easy and safe in all conditions. Potentially degraded site

Gilbreath Creek (34 34 03.7N, 85 27 16.87W): This creek is a tributary to the East Fork within Chattooga County, Georgia. This site is at a narrow section of the creek just below the bridge on Gilbreath Mill Road. The substrate is small cobble and sand. The area upstream involves the same land uses as all other sites, including reclaimed strip mines. This site is nearest to the headwaters for any site on the East Fork. Access is easy and safe in all conditions. Potentially degraded site

Park Water Resources Rank: Category 1.

Russell Cave National Monument *(August 2, 2001)*

Hydrogeology

Russell Cave (10 km long) is set against the base of the Cumberland escarpment near the head of Doran Cove. The Monument boundary extends from the limestone floor of the cove to the sandstone-capped ridge of Montague Mountain, 300 meters above. The hydrogeology of Russell Cave National Monument is typical of the base of the Cumberland Plateau. Surface water collects and flows in streams (many are seasonal) across silisiclastic rocks until underlying carbonates are encountered, whereupon they sink forming cave streams. In such situations, surface waters from several kilometers away may contribute flow to a cave stream or spring. Russell Cave National Monument contains springs (many springs are in the immediate vicinity of the Monument) and several kilometers of cave streams. The watersheds of these springs and steams are unknown as no dye-tracing has been done to date.

Past Inventories/Monitoring/Research Activities

The primary focus at Russell Cave National Monument has been on the tremendous archeological resources left by centuries of ancient human occupation. Aside from problems associated with flooding and the accumulation of trash and debris, no concerted effort has been made to fully assess the water resources of the Monument. Dr. Horton Hobbs (Whittenburg University) conducted a cave aquatic inventory between August 1992 and December 1993. During this inventory several water samples were collected and analyzed for basic parameters – mostly along the main stem of the stream in Russell Cave. The biological findings of this inventory will be discussed below.

The most striking data-gap exists not in the relative lack of water quality records, but perhaps in the absence of the most fundamental element of water resources protection and conservation – delineation of the watershed. Although water samples must be collected through the NRC Program, watershed delineation by dye-tracing must be initiated at the earliest possible time.

Associated Land Uses and Water Quality Threats

As we do not know the extent of the watershed recharging the Monument's waters we cannot be certain what land uses may be effecting the waters. We, however, can make general assumptions based on nearby land uses. Rimming the head of Doran Cove, as this hollow extends into southern Tennessee, are scores of coal mines. These mines are largely abandoned. The steep slopes of the cove are mostly forested while the broad karst valleys are in light-agriculture and rural residential use. The small community of Orme Tennessee lies within the cove north (most likely upstream) of the Monument.

Human Use and Aquatic Biology

Primary and secondary contact recreation (largely depending upon the skill and fortitude of the adventurous visitor) occurs, as people traverse the main stream of Russell Cave. This represents the only public recreation of the Monuments waters.

The cave aquatic inventory (H. Hobbs, 1994) found a very diverse community. During this inventory, eight caves within the Monument surveyed for biological diversity. Hobbs reports several aquatic species to be significant. *Apochthonius russelli*, which is found only in Russell and Reese Caves and *Pseudotremia minos*, which is only found in Russell Cave are of particular importance. An undescribed species, *Stygobromus n*. sp. and an unidentified *pseudotremia* sp. were also found in the streams of Russell Cave along with the southern cave fish (Alabama "Species of Special Concern") *Typhlichthys subterraneus*. The cave also provides habitat for several salamanders: *Plethedon glutinosus, Grinophilus porphyritcus, G. palleucus,* and *Eurycea lucifuga*.

Potential Water Quality Monitoring Locations

Russell Cave Spring: Located at Russell Cave's entrance, this is the main spring providing flow to the cave. Access is easy and safe in all conditions except during flood flow. <u>Potentially degraded site</u>

Ridley Cave: Located a few hundred meters north of Russell Cave. The flow relationship between Ridley Cave and Russell Cave Spring is not known but can safely be assumed (until proven by dye-tracing) to be upstream. Access is easy and safe in all conditions except during flood flow. <u>Potentially degraded site</u>

Picnic Entrance: Located between Ridley Cave and Russell Cave. The flow relationship between Ridley Cave, the Picnic Entrance and Russell Cave Spring is not known. Access is easy and safe in all conditions except during flood flow. <u>Potentially degraded site</u>

Park Water Resources Rank: Category 1.

Carl Sandburg Home National Historic Site *(September 4, 2001)*

Hydrogeology

Carl Sandburg Home National Historic Site is located on the edge of the Blue Ridge Mountains. The park, with approximately 150 meters of relief, is underlain by igneous and metamorphic rock. The hydrogeology is characterized by small spring-fed surface streams that flow into two man-made lakes at the base of the park. There are two main watersheds, Front Lake and Side Lake. The Front Lake watershed is headed in the southern uplands of the park at the Mountain Reservoir (the small stream supplying this pond originates from woodlands outside the park). A small stream issues from the pond and leaves the park where it flows through the Ravenswood community and into Ravenswood Lake. Water flows from the Ravenswood Lake dam and immediately into the park recharging Front Lake. The Side Lake watershed originates from a small spring that flows into the Trout Pond, the Duck Pond, and ultimately into Side Lake. Before entering Side Lake, this stream receives a tributary from the west (non-park lands). Both Trout Pond and Mountain Reservoir supply stock water for the Historic Site via buried water lines.

The water resources of Carl Sandburg Home National Historic Site provide a "text-book" water quality scenario. Water quality can be monitored in two watersheds upstream and downstream from the potential impacts of non-park activities as both streams originate in the park, leave the park (or join outside tributaries), and re-enter the park downstream.

Past Inventories/Monitoring/Research Activities

Carl Sandburg Home National Historic Site began conducting water quality monitoring in the mid-1970's. During two periods, 1977-1978 and 1988-1993, sampling focused on Trout Pond, Front and Side Lakes. Sample analysis targeted nutrients and chlorophyll A. This park-initiated monitoring represents the only water quality data generated at the Site. Aquatic biological inventories are incomplete.

Associated Land Uses and Water Quality Threats

Threats to water quality are largely related to residential land use as the streams either leave and re-enter the park (Front Lake) or pick up a tributary (Side Lake). Portions of the watersheds that are external to the park have moderate residential development. The Ravenswood community (Front Lake) relies on individual septic systems for wastewater treatment. Aside from increased nutrient loads, lawn chemicals may be a potential water quality threat. Land use impacts from within the park from a small livestock (goat) operation may include animal waste runoff. The Sandburg home will be connected to a sewer system in late 2001. Currently wastewater from the Sandburg home is treated in a leech field in a pasture above Side Lake.

Human Use and Aquatic Biology

No water recreational activities occur within the park. Aquatic biological inventories are incomplete at this time.

Potential Water Quality Monitoring Locations

Trout Pond Spring: Located approximately 100 meters upstream of the Trout Pond. This small, perennial spring is the headwater of the Side Lake watershed. The spring has been "improved" several years ago by the NPS. The spring was buried under rubble and a spring-box was constructed with an 8,000 underground supply tank that feeds the barn operation via a buried pipe. Access to the spring, through the spring box (upstream from the tank), is easy and safe in all conditions. <u>Pristine site</u>

Side Lake: Located on the northern edge of the park, this man-made lake is the extreme downstream end of the Side Lake watershed. The lake is fed by waters of Trout Pond Spring and an unnamed non-park tributary. Access to the lake is easy and safe in all conditions. <u>Potentially degraded site</u>

Mountain Reservoir: Located in the southern uplands of the park, this small pond is fed by a small stream originating from undeveloped woodlands adjacent to the park. This site represents the headwaters of the Front Lake watershed. Access is easy and safe in all conditions. <u>Pristine site</u>

Front Lake: Located on the northeastern edge of the park, this man-made lake is the extreme downstream end of the Front Lake watershed. The lake is fed by the waters of the Mountain Reservoir which flows through the Ravenswood community before entering Front Lake. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

Park Water Resources Rank: Category 2.

Ninety Six National Historic Site *(September 5, 2001)*

Hydrogeology

The site visit was made during a drought that began in 1996. The gently rolling lands of Ninety Six national Historic Site, located in the heart of the Piedmont, are dissected by small streams. One stream, Spring Branch, originates within the park near the historic village of Ninety Six. Spring Branch, which was dry in the upstream stretches during the site visit, flows south into Ninety Six Creek. A discharge of less than 1 l/min was observed in the lower portion of Spring Branch near Ninety Six Creek. Ninety Six Creek (which had been dry just prior the visit, but recent showers stimulated a flow of approximately 4 l/min) originates from an area dominated by woodlands and light agriculture west of the park. Aside from a small wooded pond, the remaining water resource in the park is the ten-hectare Star Fort Lake located in the northeastern section of the park. This man-made lake is recharged by two small streams originating from woodlands and light agriculture to the north. Discharge from Star Fort Lake's dam flows into Ninety Six Creek at the park's eastern boundary.

Past Inventories/Monitoring/Research Activities

No past or current water quality studies have been done at Ninety Six national Historic Site. No aquatic biological inventories have been done at this time.

Associated Land Uses and Water Quality Threats

Land uses are limited to woodlands, light agriculture, and a few residences within the watershed of Ninety Six Creek and Star Fort Lake. Although the watershed of Spring Branch is not known, it can be reasonably assumed that this very small stream is recharged by lands within the historic development area of the park.

Human Use and Aquatic Biology

Secondary contact recreation (fishing and canoeing) occurs at Star Fort Lake. Swimming is not allowed. No other water-related recreational activities take place within the park.

Potential Water Quality Monitoring Locations

Spring Branch: Located along the western portion of the park, this stream (generally perennial except for times of extended drought) is recharged by a series of small seeps. The best sampling location is near the confluence with Ninety Six Creek along the Gouedy Trail. Access is easy and safe in all conditions. <u>Pristine site</u>

Ninety Six Creek: Located along the southern edge of the park, Ninety Six Creek is the largest stream in the park. The best sampling location for this perennial (except during times of extreme and extended drought) is just upstream of its confluence with Spring Branch along the Gouedy Trail. Access is easy and safe in all conditions. <u>Potentially degraded site</u>

Star Fort Lake: This ten-hectare lake is located in the northeastern portion of the park. Depending on the park's management objectives of this lake, samples could be taken in either the lake, the unnamed northwestern tributary to the lake, or in the outflow of the dam. In any case, access is easy and safe in all conditions. <u>Potentially degraded site</u>

Park Water Resources Rank: Category 3.

Cowpens National Battlefield *(September 6, 2001)*

Hydrogeology

Unlike many parks with watersheds reaching far beyond boundaries, Cowpens National Battlefield forms the headwaters of several small streams. The extreme headwaters of the streams are characterized by small seeps that supply base-flow recharge. Streams which contain several seeps tend to flow perennially while many only flow seasonally.

Past Inventories/Monitoring/Research Activities

Two water quality studies were recently completed by the University of South Carolina, Spartenburg. The study "Water Quality Assessment of Cowpens National Battlefield (Turner, et al., 2001) represents bi-weekly sampling of eight streams at points where they left the park lands between February 2000 and March 2001. The investigators examined fecal coliform, *E. coli*, chloride, ammonia, nitrate, sulfate, sodium, potassium, magnesium, calcium, iron, manganese, phosphate, alkalinity, temperature, dissolved oxygen, specific conductance, and pH. Over the course of the study, several of the streams went dry (summer and early autumn months). Although each stream displayed seasonal variability in nearly each ionic parameter, there were no exceedences (not even close) of state standards for fish and aquatic life. There were several periods of elevated fecal coliform in every stream in the park. Each stream had fecal coliform concentrations above primary contact limits of 200 colonies/100 ml, some as high as 3500 colonies/100 ml. Another study "Determination of Fecal Coliform Contamination in Creeks Exiting Cowpens National Battlefield" (Clark, 1999) included two sampling rounds in April, 1999 at eight and 19 locations. Fecal coliform values ranged from 2-570 colonies per 100/ml.

Associated Land Uses and Water Quality Threats

As each stream in Cowpens National Battlefield originate from within the park, the only land uses, and thus threats, are either natural or park created. These lands include limited development in two areas; the Visitor Center and Picnic grounds. Wastewaters are treated with septic systems. Other developments within this wooded to open park include a five kilometer loop road circles the main battlefield and the nature trail (hike, bike, horse) near the Picnic grounds.

Human Use and Aquatic Biology

No water recreational activities occur within the park. The nature trail crosses Long Branch and tributaries at foot bridges. Aquatic biological inventories at Cowpens are incomplete.

Potential Water Quality Monitoring Locations

Long Branch of Island Creek: Located at the southern edge of the park this site is the largest watershed in the park. It is labeled as "Site 5" in the 2001 study. This creek and its tributaries drain the nature trail and Picnic Grounds areas. Flow was approximately 7 l/sec during visit. Access is gained from State Route 36 (Bonner Road) and is easy and safe in all conditions. <u>Potentially degraded site</u>

Little Buck Creek: Located in the northwestern portion of the park this site ("Site 8 in the 2001 study) is accessed from State Route 110. Samples should be taken before water enters the drainage culvert under State Route 110. Flow was approximately 2 l/min during visit. Access is safe and easy in all conditions. <u>Pristine site</u>

Suck Creek #2: Located in the northeastern portion of the park this site ("Site 2 in the 2001 study) is accessed from State Route 11. Samples should be taken before water enters the drainage culvert under State Route 11. Flow was approximately 2 l/min during visit. Access is safe and easy in all conditions. <u>Pristine site</u>

Suck Creek #3: Located in the eastern portion of the park this site ("Site 3 in the 2001 study) is accessed from State Route 11. Samples should be taken before water enters the drainage culvert under State Route 11. Flow was approximately 2 l/min during visit. Access is safe and easy in all conditions. <u>Pristine site</u>

Park Water Resources Rank: Category 3.

Kings Mountain National Military Park *(September 7, 2001)*

Hydrogeology

Located at the western edge of the Piedmont, Kings Mountain National Military Park is drained by numerous perennial surface streams. This 1,600 hectare park is underlain to a large extent (if not entirely) by igneous rocks. One small spring (flow less than 1 l/min) is found along the Battlefield Trail. All streams, with the exception of a short stretch of Kings Creek (which forms a portion of the park's northwestern border), originate on park lands. To the east and south the park borders Kings Mountain State Park.

Past Inventories/Monitoring/Research Activities

Kings Mountain National Military Park was involved in monthly water quality sampling between January 1994 through January 1997. These samples covered basic parameters including temperature, specific conductance, dissolved oxygen, pH, discharge, fecal coliform, total dissolved solids, and turbidity. All parameters were within limits for fish and aquatic life, while fecal coliform exceeded primary contact limits on occasion at one location (Dellingham Branch near Kings Creek confluence).

Associated Land Uses and Water Quality Threats

With exception of Kings Creek and the downstream stretch of Dellingham Branch, all streams in Kings Mountain National Military Park drain park lands. The park is very active in fire management and allows horseback riding on its trails. Such activities may be reflected in certain water quality parameters. Kings Creek forms about one kilometer of the park's northwestern boundary. Land use within the Kings Creek drainage includes light agriculture, forest and a few homes. During the site visit several bovine (from adjacent private land to the north) were found lounging in Kings Creek near the confluence of Stonehouse Branch. The final half kilometer of Dellingham Branch also forms a portion of the park's northwestern boarder. Although several cows were observed adjacent to this creek, without trespass it was not possible to determine if they had access to the creek.

Human Use and Aquatic Biology

Little or no primary contact recreational activity occurs in park waters. It is very possible that an occasional visitor might wade into streams such as Long Branch or Garner Branch at trail crossings. The streams appear to be far to small to support sport fishing opportunities. An aquatic biologic inventory is incomplete at this time.

Potential Water Quality Monitoring Locations

Five excellent (in terms of access, relationship to park drainages, and data history) can be found at the park.

Long Branch: This stream, which drains the primary front-country attraction (Visitor Center area and Battlefield Trail) can be sampled at the boundary of the state park. The boundary is reached after a two kilometer trail hike from the Visitor Center. Access is easy and safe in all conditions. <u>Pristine site</u>

Garner Branch: This stream is located in the southwestern portion of the park and can be accessed via a hiking trail (about 1.5 km) from the Piedmont Road within the state park. The sampling location is within the National Park at the trail crossing. Access is easy and safe in all conditions. <u>Pristine site</u>

Dellingham Branch: This stream is primarily recharged by park lands with the exception of its final 0.5 km, which boarders private, agricultural lands (primarily pasture). The stream can be sampled at its confluence with Kings Creek. Access to this point would be made much easier is permission from landowner is granted to traverse the pasture adjacent to Kings Creek (south side). Past sampling occurred approximately 250 meters above the confluence of Kings Creek. Access is easy and safe in all conditions. <u>Degraded site</u>

Stonehouse Creek: This stream is recharged entirely by park lands and can be sampled at its confluence with Kings Creek. Access is gained via a park road to the Stonehouse, which leads to the Kings Creek floodplain (the road was closed during the site visit as I hiked from the Rockhouse Bridge). Access is easy and safe in all conditions. <u>Pristine site</u>

Kings Creek: The largest stream in the park can be sampled at the bridge of Rockhouse Road. This site is representative of waters entering the park from the private lands to the north. Access is easy and safe in all conditions. <u>Degraded site</u>

Park Water Resources Rank: Category 2.

Guilford Courthouse National Military Park *(September 10, 2001)*

Hydrogeology

Situated on the Piedmont of central North Carolina, Guilford Courthouse National Military Park is drained by two small streams. The larger of the two, Richland Creek, enters the park from the south from the adjacent Greensboro Country Park. This municipal park dams the creek in two successive lakes before it flows into national park lands. Richland Creek picks up a small tributary within the park near the trail leading from the historic site of Guilford Courthouse. This tributary begins as a small stream within the park adjacent to the Forest Lawn Cemetery.

Past Inventories/Monitoring/Research Activities

The limited aquatic resources of Guilford Courthouse have received a fairly complete water quality inventory. Between July 1996 and February 1998, a series of monthly samples were taken from Richland Creek. These samples were analyzed for a wide variety of metals, nutrients, bacteria, and standard field parameters. The only parameters that exceeded acceptable levels were fecal coliform (as high as 7,000 colonies/100ml) and fecal streptococci (as high as 80,000 colonies/100ml).

Associated Land Uses and Water Quality Threats

Guilford Courthouse National Military Park is abutted on all sides by urban Greensboro. The main stream in the park, Richland Creek, drains commercial and residential lands. Prior to entering the park, the creek is dammed into two small lakes in Greensboro Country Park. Several dozen ducks and geese were found on and around these lakes (and maybe a contributor of the high bacterial counts in Richland Creek. High bacterial counts may also be from a leaky sewer line that runs directly through the park.

Human Use and Aquatic Biology

No primary of secondary contact recreational activities occur within the park. There has not been an aquatic biological inventory done at the park.

Potential Water Quality Monitoring Locations

Richland Creek: Samples may be taken at the culvert that takes Richland Creek beneath the park's tour loop road. This site is just downstream from where the creek enters the park. Access is easy and safe in all conditions. <u>Degraded site</u>

Spring: The unnamed spring that perennially discharges in the park adjacent to the Forest Lawn Cemetery can be accessed from the tour loop road. Access is easy and safe in all conditions. Potentially degraded site

Park Water Resources Rank: Category 3.

Abraham Lincoln Birthplace National Historic Site *(October 21, 2001)*

Hydrogeology

Abraham Lincoln Birthplace National Historic Site consists of two areas, each with distinctly different hydrogeology. The main unit (the birthplace) displays the classic karst hydrogeology of the Pennyroyal Plateau as all surface water is diverted into the underling limestones. The central natural resource feature of the park is Sinking Spring (a karst window) which lies in the bottom of a large sinkhole in the center of the park. Groundwater tracer studies have delineated its watershed (James Quinlan, Mammoth Cave National Park, 1978; Joe Ray, Kentucky Division of Water, 1993, and Western Kentucky University, 1998). Groundwater that flows into Sinking Spring travels to Talley Spring on the South Fork of the Nolin River 1.2 kilometers to the southwest. The Knob Creek farm to the north is located at the base of the Muldraugh Hill escarpment. Water is generally confined to flowing over siltstones and shales in seasonal surface streams. The Knob Creek Farm (Abe's boyhood home) is in the final stages of acquisition by the NPS at this time, and will officially become part of the park on February 13, 2002.

Past Inventories/Monitoring/Research Activities

During the late 1990's the Kentucky Division of Water sampled Sinking Spring as part of its Ambient Water Quality Program. These grab samples, generally taken quarterly, showed slightly elevated levels of nitrate and seasonal detection of agricultural chemicals (mostly atrazine). In 2001 the Hoffman Environmental Research Institute of Western Kentucky University (HERI) was contracted to examine the water quality of Sinking Spring during flood pulse events. Research at Mammoth Cave has shown that the highest degree of water quality degradation is associated with flood pulses – rainfall events that literally flush non-point source contaminants into the karst aquifer. Preliminary results of this study have shown elevated levels of fecal coliform (over 10,000 colonies/100 ml).

In addition to water quality monitoring, the NPS contracted HERI to perform groundwater dye tracer studies to define the watershed of Sinking Spring (1998). Following the basin delineation, detailed landuse surveys were conducted. High-resolution areal photographs were taken (which also produced detailed topographic maps of the park) to assign Anderson Level 3 landuse values.

No water quality sampling has occurred at the Knob Creek Farm.

Associated Land Uses and Water Quality Threats

The landuses within the watershed of 0.5 km^2 Sinking Spring groundwater basin is largely confined to the topographic depression surrounding the spring (WKU, 1999). Sinking Spring's watershed includes relatively light land use pressures. US31W is present within the basin for only a very small portion at the park's entrance road intersection. The drainage west of the park includes light agricultural uses, reflected in detections of herbicides in Sinking Spring. Other land uses include the park's maintenance area (fuel storage) and the park's visitor parking lot. Within this large sinkhole is an internal drainage system installed by the U.S War Department in 1929. All drainage from this system enters Sinking Spring via a main culvert. All flow from Sinking Spring ultimately discharges at Talley Spring on the South Fork of the Nolin River.

Human Use and Aquatic Biology

No primary or secondary contact recreational activities occur in park waters. No aquatic biological inventories have been done at this time.

Potential Water Quality Monitoring Locations

Sinking Spring: Located near the center of the main park unit, Sinking Spring is the major natural resource attraction in the park. Interpreted as the first drink of water taken by the infant Lincoln, protecting water quality at Sinking Spring is very important to park management goals. The site has been the focus of past water quality efforts and can be easily and safely access in all conditions. <u>Degraded site</u>

North Branch Knob Creek: Located within the Knob Creek Farm unit of the park, the North Branch of Knob Creek is the largest stream. The watershed is primarily comprised of forested land in the uplands and open pasture in the bottoms. Samples should be taken in this stream (which dries in the late summer-early autumn) at the extreme downstream end of the branch adjacent to the developed portion. Access is easy and safe in all conditions. <u>Pristine site</u>

Park Water Resources Rank: Category 2.

Cumberland Gap National Historic Park *(November 20, 2001)*

Hydrogeology

Cumberland Gap National Historic Park possesses the widest variety of hydrogeologic conditions within the CPN. The entire park is underlain by a sequence of sedimentary strata – ranging from Devonian shales, through Mississippian limestones, to Pennsylvanian coals and silisiclastics. Geologic structure is abundant in the park as the mountains themselves the result of an overthurst fault, and crossed by normal and reverse faulting – resulting in the Gap itself. Many surface streams originate upon the steep slopes of Cumberland Mountain flowing both westward into Kentucky and eastward into Virginia and Tennessee. Some streams, where they cross the steeply dipping limestones, are captured to the subsurface recharging karst aquifers and discharging at springs.

Past Inventories/Monitoring/Research Activities

The steams of the park, largely thanks to the construction of the Cumberland Gap Tunnel and restoration of the Wilderness Road in the mid-1980's through the present, have undergone the most intensive water quality monitoring of the CPN. This effort has focused on the many streams, ranging from the larger Little Yellow Creek (Kentucky) and Gap Creek (Tennessee) to smaller tributaries like Tunnel Creek and Railroad Creek (Kentucky), all which drain the tunnel and restoration areas. Water quality sampling continues presently in support of the Gap restoration project.

Although aquatic inventories have not been completed, much monitoring has been done with respect to the ESA threatened Blackside dace (*Phoxinus cumberlandensis*). This fish currently occurs only within a short reach of Davis Branch just above Middlesborough. The park contracts annual monitoring of the Blackside dace along this reach of Davis Branch. At this time there have been no aquatic inventories of Cudjo Cave.

Brook trout have been stocked immediately downstream from the park boundary in Shillalah Creek and Martin Fork. The Kentucky Division of Fish and Wildlife has monitored the trout populations over the years and note a declining trend in the fish, which coincides with a declining pH trend.

Associated Land Uses and Water Quality Threats

With the exception of a small area of Middlesborough Kentucky supplying urban runoff into Little Yellow Creek (this runoff enters the far downstream reach of the stream nearly at the park boundary) and the town of Cumberland Gap Tennessee (complete with a waste-water treatment facility), the streams of the park originate from park lands. One further exception is the aforementioned streams, which are, in part, recharged by the tunnel and its roadways. As a testament to streams dominated by undeveloped forest lands (most of which are within a proposed Wilderness Area), water quality of these streams can be considered pristine – a rare occurrence in the Appalachians.

Human Use and Aquatic Biology

Only incidental primary recreational contact occurs within the park's waters, as its streams are too small for swimming. Secondary contact recreation is also limited, and, due to lack of reproduction of brook trout, fishing within the park's trout streams (Shillalah Creek and Martin Fork) is closed at this time.

Unlike any other park of the CPN, Cumberland Gap National Historic Park supplies one, and with the possible addition of Fern Lake, two public drinking water supplies. The stream of Cudjo Cave is the drinking water source of Lincoln Memorial University in nearby Harrogate Tennessee. Fern Lake, whose addition to the park has been approved by Congress and awaits real estate negotiation (which could take up to two years to complete), is the drinking water source for Middlesborough Kentucky (including the park headquarters area).

Two streams within the park are home to brook trout – Martins Fork and Shillalah Creek. Reproduction of these trout have ceased over the past six to eight years for an unknown reason. The Kentucky Division of Fish and Wildlife continue to stock these streams. Although this stocking program (a combination of fish from the Great Smoky Mountains National Park and state hatcheries) began ten years ago, anecdotal evidence suggests the historic occurrence of these fish in these streams.

The park also supports one ESA aquatic specie, the Blackside Dace. This fish, undoubtedly historically occurring over a wider range, is now limited to a short stretch in the lower portion of Davis Branch as it flows into Middlesborough near the confluence of Little Yellow Creek.

Potential Water Quality Monitoring Locations

Each of the potential water quality monitoring locations listed below have been used for past monitoring studies. Parenthetical notations refer to site codes used by CUGA.

Little Yellow Creek, Upstream (YC1): This site is located where Little Yellow Creek enters the present park boundary. It is just downstream from Fern Lake Dam (public drinking water supply for Middlesborough Kentucky). The majority of the watershed is forested with several abandoned strip mines (coal). Water quality records do not show an impact from these mines. Access is easy and safe in all conditions. <u>Pristine site.</u>

Davis Branch (DB10): Located where Davis Branch leaves the park (immediately adjacent to the city of Middlesborough). Blackside Dace are located just upstream from this site. Land use is park lands. Access is easy and safe in all conditions. <u>Pristine site.</u>

Little Yellow Creek (YC12): Downstream from the confluence of Davis Branch, this site also receives runoff from a small portion of Middlesborough as well as the park's maintenance area. This site is where Little Yellow Creek exits the park at the intersection of US25E. Access is easy and safe in all conditions. Potentially degraded site.

Tunnel Creek (TC10): Located along Pinnacle Road, this perennial stream, which prior to the construction of the tunnel was a seasonal stream, receives recharge from US25E leading to the tunnel as well as drainage from the Kentucky side of the tunnel. Access is easy and safe in all conditions. Potentially degraded site.

Railroad Creek (RR1): Located just off Pinnacle Road, this small perennial stream receives flow from the railroad tunnel as well as runoff from the restoration project area along the Wilderness Road. This stream discharges into Davis Branch above the Blackside Dace habitat. Access is easy and safe in all conditions. Potentially degraded site.

Sugar Run (SR10): Draining park lands, this perennial stream flows along Sugar Run Road and is adjacent to a picnic area, complete with a septic system. Past monitoring does not show impact from septic system. Access is easy and safe in all conditions. Pristine site.

Shillalah Creek (SH10): Primary sampling site is located as the stream exits the park and enters Kentucky Wildlife Management Area. This stream contains brook trout, but monitoring indicates a loss in reproduction of stocked fish, perhaps coincidental with a decline of pH. This stream is very high gradient as it falls over large boulders as it flows down the western slope of Cumberland Mountain. It is headed at the Hensley Settlement, which has had a history of fertilizer and lime application (since discontinued). Secondary site is along Shillalah Creek further downstream within the Wildlife Management Area. Access is easy and safe in all conditions with the exception of snow and ice, which would render the road hazardous. Pristine site.

Gap Creek (GC7): Located at the railroad bridge and downstream from the town of Cumberland Gap Tennessee and the town's waste-water treatment plant. This site is recharged by a combination of drainage from the tunnel, Giles Spring (fed by the tunnel cave), Cudjo Cave, and runoff from the town. Access is easy and safe in all conditions. Degraded site.

Station Creek (ST10): Located as Station Creek leaves the park and passes under SR58, this stream is recharged by park lands, including the park campground (septic system). Access is easy and safe in all conditions. Potentially degraded site.

Martin Fork: Located in the remote northeastern portion of the park, this stream might be added to the list of monitoring stations. Its remoteness (perhaps manifested in its relatively pristine condition) makes this a very difficult site to access. There are three feasible ways to monitor this stream (which like Shillalah Creek is stocked with brook trout and has a declining pH): 1) The stream might be sampled at a roadway crossing downstream of the park, 2) Sample at a less frequent basis within the remote area, 3)

Require individuals that may monitor biological resources (bogs for example) to collect a water sample when they are in the area. In any case, this appears to be an important stream to monitor. Access ease and safety depends of final site selection. Pristine site.

Park Water Resources Rank: Category 1.

Water Quality Monitoring Program

Introduction

Paramount to the conservation of the surface and subsurface aquatic ecosystems of a park, is the knowledge of and the ability to recognize long-term trends in water quality. Over the next few years many inventory efforts, including those pertaining to aquatic biota, will be conducted throughout the Cumberland-Piedmont Network (CPN). For the first time many park managers and researchers will be able to see the effects of landscape-scale use and change upon the dependent aquatic ecosystems. Central to any long-term aquatic monitoring effort are water quality monitoring data. Through recent research at Mammoth Cave, built upon a scientifically sound and statistically rigorous program by the United States Geological Survey (USGS) we have determined the most accurate methods and protocols for surface and groundwater sampling. We know that a solid program be based upon non-conditional synoptic sampling in order to track long-term trends in water quality.

To better understand threats to the aquatic ecosystems it is necessary to have a basic understanding of the relationship between park waters and their watersheds. Many parks within the CPN are recharged by land outside park boundaries. Each land-use that occurs within a particular watershed contributes to the overall water quality. It must be noted that the parks themselves are not immune to contributing to water pollution, including roadways, parking lots, developmental erosion, pesticide and fertilizer use, and septic fields. Some land-uses produce contaminants, which can be divided into three main categories:

> **Acute Non-Point Source:** Agricultural pollutants (animal waste, suspended sediments, and pesticides) and some urban pollutants (parking lot and road runoff) accumulate on the surface in virtual storage until they are washed into the streams or aquifers during rainfall events. Each year thousands of tons of sediments, animal wastes, nutrients, and pesticides are introduced into the streams of CPN parks from these lands.
>
> **Chronic Non-Point Source:** From land-uses such as oil and gas exploration and production (hydrocarbons and brines), urban development (septic waste), and agriculture (wastes deposited directly into streams), these pollutants are released into the watersheds at a relatively steady rate, regardless of precipitation.
>
> **Point-Source:** Traversing the watersheds of many parks are transportation corridors. These roadways and railroads are sources of spills of hazardous materials. Any contaminant released along these routes is quickly washed into park streams.

Simply stated, any land use practices within the parks' watershed can directly impact the parks' water quality.

Sampling Program

Developed primarily from protocols of the USGS National Water Quality Assessment (NAWQA) Program, the CPN Water Quality Program is based upon fixed-site, synoptic, non-conditional sampling strategies. The Basic Fixed-Site sampling is designed to provide an integrated assessment of the spatial and temporal distribution of general water-quality conditions and the transport of major inorganic constituents of streamwater in relation to hydrologic conditions and major sources (USGS Circular 1112). Data from Basic Fixed-Site sampling are the primary source of information for meeting water-column assessment objectives for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon. Site selection and sampling strategy for Basic Fixed Sites are based on balancing needs and priorities for assessing water-column conditions, constituents in bed sediment and tissues, and ecological characteristics.

The fixed monthly, bi-monthly, or quarterly (based upon Water Resources Ranking) sample set provides comparative statistics for the selected sites and parameters under variable flow conditions. Similar to the NAWQA, topical surveys are included in the program to further elucidate anomalies found during the synoptic sampling. For example, if synoptic sampling revealed high concentrations of bromide, a topical study would be developed to examine possible source areas of brine (usually associated with hydrocarbon extraction) through additional sampling stations and examination of related ions.

Supported by the MACA LTEM Water Quality Laboratory, the CPN can go far beyond the core parameters (temperature, specific conductance, pH, and dissolved oxygen) required for the Natural Resources Challenge Program. Additionally, field-stationed CPN personnel (data-managers, one at RUCA and one at KIMO) will collect samples from proximal parks. Each data-manager will be field trained at specific parks at the exact sampling points. The current data-managers both have strong natural resources backgrounds (ecology and aquatic biology).

All data collected under this program, from field data through laboratory analysis – including data entry and validation, will be done in accordance with the Quality Assurance Plan (Attached).

Monitoring Responsibilities and Logistics

The following sampling schedule is largely based upon the USGS NAWQA program. "Category One" parks will follow the NAWQA non-conditional synoptic sampling schedule; i.e., monthly sampling on fixed calendar dates, regardless of flow conditions for a period of two years, followed by five off years. The USGS has found that such sampling will provide a statistically valid long-term data set. Groupings are based on personnel field and lab time. There will be three field offices responsible for sampling: MACA, RUCA, and KIMO. MACA hydrologists will sample MACA, STRI, FODO, ABLI, and CUGA (although it is possible that CUGA will provide an in-park sampler by FY07). RUCA CPN database manager will sample RUCA, CHCH, SHIL, and LIRI (current personnel at LIRI will allow sampling at that park). KIMO CPN database manager will sample KIMO, CARL, COWP, GUCO, and NISI. Mammoth Cave, although funded separately from the CPN WQ ($59K/annum), will be listed below, as WQ monitoring at MACA must be accounted for relative to lab and personnel time. MACA is considered a "Category One" park with respect to water resources.

Non-conditional sampling will occur on the 2nd (NCS2), 10th (NCS10), and 20th (NCS20) day of each month. Exact dates of bi-monthly (BM, every other month) and quarterly samples (Q, every three months) are to be determined but will fall within a one-week period common to each park. Each park listed below includes all sampling stations plus one QA/QC duplicate sample per round.

Field Offices: MACA RUCA KIMO.

FY03

Sample	Park	Field Office	#samples	#samples/year
NCS2	STRI	MACA	6	72
NCS10	MACA	MACA	14	168
NCS20	CHCH	RUCA	8	96
BM	KIMO	KIMO	6	36
Q	CARL	KIMO	5	20
Q	COWP	KIMO	6	24
				416

Samples per field office/year: MACA: 240, RUCA: 96, KIMO: 80
Estimated field days/year: MACA: 24, RUCA: 12, KIMO: 14

FY04

Sample	Park	Field Office	#samples	#samples/year
NCS2	STRI	MACA	6	72
NCS10	MACA	MACA	14	168
NCS20	CHCH	RUCA	8	96
BM	ABLI	MACA	3	18
Q	GUCO	KIMO	3	12
Q	NISI	KIMO	4	16
Q	FODO	MACA	3	12
				394

Samples per field office/year: MACA: 272, RUCA: 96, KIMO: 28
Estimated field days/year: MACA: 34, RUCA: 12, KIMO: 8

FY05

Sample	Park	Field Office	#samples	#samples/year
NCS2	RUCA	RUCA	4	48
NCS10	MACA	MACA	14	168
NCS20	SHIL	RUCA	9	108
BM	KIMO	KIMO	6	36
Q	CARL	KIMO	5	20
Q	COWP	KIMO	5	20
				400

Samples per field office/year: MACA: 168, RUCA: 156, KIMO: 76
Estimated field days/year: MACA: 12, RUCA: 24, KIMO: 14

FY06

Sample	Park	Field Office	#samples	#samples/year
NCS2	RUCA	RUCA	4	48
NCS10	MACA	MACA	14	168
NCS20	SHIL	RUCA	9	108
BM	ABLI	MACA	3	18
Q	GUCO	KIMO	3	12
Q	NISI	KIMO	4	16
				370

Samples per field office/year: MACA: 186, RUCA: 156, KIMO: 28
Estimated field days/year: MACA: 18, RUCA: 24, KIMO: 8

FY07

Sample	Park	Field Office	#samples	#samples/year
NCS2	LIRI	RUCA	11	132
NCS10	MACA	MACA	14	168
NCS20	CUGA	MACA	10	120
BM	KIMO	KIMO	6	36
Q	CARL	KIMO	5	20
Q	COWP	KIMO	6	24
				438

Samples per field office/year: MACA: 288, RUCA: 132, KIMO: 80
Estimated field days/year: MACA: 48, RUCA: 12, KIMO: 14

FY08

Sample	Park	Field Office	#samples	#samples/year
NCS2	LIRI	RUCA	11	132
NCS10	MACA	MACA	14	168
NCS20	CUGA	MACA	10	120
BM	ABLI	MACA	3	18
Q	GUCO	KIMO	3	12
Q	NISI	KIMO	4	16
Q	FODO	MACA	3	12
				478

Samples per field office/year: MACA: 318, RUCA: 132, KIMO: 28
Estimated field days/year: MACA: 58, RUCA: 12, KIMO: 8

Water Quality Parameters; Field Measures

The following text is adapted from the USGS Techniques of Water-Resources Investigations Book 9, Chapters A1-A9 (2001). All equipment specifications and calibration procedures are outlined in this document.

Discharge: The anchor of all water quality data. Discharge data are used to compute the mass flux, or loading, of a particular constituent. Mass flux yields valuable insight as to the mode of contaminant entrainment and transport through the watershed.

pH: The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions. Water pH is a useful index of the status of equilibrium reactions in which water participates. The pH of water directly affects physiological functions of plants and animals, and it is, therefore, an important indicator of the health of a water system. The electrometric measurement method uses a hydrogen ion electrode. This is the only technique that is approved for measuring pH values that are to be reported or entered into the USGS database.

Specific Conductance: Electrical conductance is a measure of the capacity of water (or other media) to conduct an electrical current. Electrical conductance of water is a function of the types and quantities of dissolved substances in water, but there is no universal linear relation between total dissolved substances and conductivity. A dip-cell electrode sensor will be used.

Temperature: Measurements of water and air temperatures at the field site are essential for water-data collection. Determinations of dissolved-oxygen concentrations, conductivity, pH, rate and equilibria of chemical reactions, biological activity, and fluid properties rely on accurate temperature measurements. Accurate water- and air-temperature data are essential to document thermal alterations to the environment caused by natural phenomena and by human activities. A thermistor thermometer is an electrical device made of a solid semiconductor with a large temperature coefficient of resistivity. An electrical signal processor (meter) converts changes in resistance to a readout calibrated in temperature units. Thermistors commonly are incorporated in instruments used for surface-water and groundwater measurements.

Dissolved oxygen: Accurate data on concentrations of dissolved oxygen (DO) in water are essential for documenting changes to the environment caused by natural phenomena and human activities. Sources of DO in water include atmospheric reaeration and photosynthetic activities of aquatic plants. Many chemical and biological reactions in ground water and surface water depend directly or indirectly on the amount of oxygen present. Dissolved oxygen is necessary in aquatic systems for the survival and growth of many aquatic organisms. The most commonly used field method for measuring DO in water is the amperometric method, in which DO concentration is determined with a temperature-compensating instrument or meter that works with a polarographic membrane-type sensor.
ANC: is the acid-neutralizing capacity of solutes plus particulates in an unfiltered water sample, reported in equivalents per liter (or milliequivalents or microequivalents per liter). ANC is equivalent to alkalinity for samples without titratable particulate matter. Based on field titrametric analysis, ANC will be determined using the ANC equation as described in Section 6.6.5.A.

Water Quality Parameters; Laboratory Measures

Turbidity: Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Primary contributors to turbidity include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and microscopic organisms. The measurement is qualitative and cannot be correlated directly as micrograms per liter of suspended solids. Measurements will be made in the laboratory with a nephelometer using Standard Method 214 A.

Fecal coliform bacteria: Fecal indicator bacteria are used to assess the quality of water because they are not typically disease-causing, but are correlated to the presence of several waterborne disease-causing organisms (pathogens). The concentration of indicator bacteria (the term "indicator bacteria" is used synonymously with fecal indicator bacteria in this section) is a measure of water safety for body-contact recreation or for consumption. The most widely used indicator bacteria are of the total coliform, fecal coliform, enterococci, and fecal streptococci groups, and E. coli. We will use fecal coliform bacteria, membrane-filtration, Standard Method 9222 D.

Atrazine: Atrazine, a triazine-class herbicide, represents the most common and durable pesticides used in the United States. They are commonly found after peak applications periods (spring), closely associated with storm pulses (attached to fine particulate matter), and have been found persisting in the water column for six months. We will use the Dionex ion chromatograph for analysis.

Chlorophyll-a: Since chlorophyll-containing organisms are the first step in most food chains, the health and /or abundance of these primary producers will have cascading effects to all higher organisms. Therefore, the determination of chlorophyll concentration is one of the key indices in monitoring the health of any natural system. We will use either Standard Method 10200 H, or EPA Method 445.0.

Total Organic Carbon: TOC is a measure of organic carbon in water, including various constituents in various oxidation states. This is a direct and easy measure of organic carbon, including components of BOD and COD. We will use Standard Method 5310 B.

Total Suspended Solids: While turbidity measures are a quick and simple estimation of suspended solid loads, it cannot be directly correlated to TSS, which is a true measure of suspended solids due to particle size and color characteristics. We will use Standard Method 2540 E.

Cations: A suite of cations (lithium, sodium, ammonium, potassium, magnesium, and calcium) will be analyzed. We will use the Dionex ion chromatograph (method under ASTM review) for these ions.

Anions: A suite of anions (fluoride, chloride, nitrite, bromide, nitrate, phosphate, and sulfate) will be analyzed. We will use the Dionex ion chromatograph, Standard Method 300.1.

Transition metals: A suite of transition metals (iron III, lead, copper, cadmium, manganese, cobalt, zinc, and nickel) will be analyzed. We will use the Dionex ion chromatograph (Dionex Technical Document 03118, revision 4) for these ions.

Water Quality Standards

As discussed below, each water body sampled within the CPN has either been assigned a designated use by the state, or, by using the same ranking criteria, by this author. The USEPA, besides mandating these rankings, also directed the states to develop water quality standards for each designated use. We can use these water quality standards as a minimum to track water quality trends in CPN parks. By adapting the states' standards, we can also track park water quality trends within the states, regions, or watersheds. Although it would be convenient to list all water quality standards for each designated use for each state in this document, transcribing these lists would be very time consuming. Instead, specific state documents that contain both designated use classifications and water quality standards will be listed below.

Alabama: Alabama Department of Environmental Management; Water Division – Water Quality Program, Chapter 335-6-10.

Georgia: Rules and Regulations for Water Quality Control, Chapter 391-3-6, Revised July 2000.

Kentucky: 401 KAR 5:026. Designation of Uses of Surface Waters.

North Carolina: Subchapter 2B – Surface Water and Wetland Standards, 15A NCAC 02B .0100 - .0510.

South Carolina: Water Classifications and Standards (R.61-68) Classified Waters (R.61-69).

Tennessee: Rules 1200-4-3-01, Tennessee Department of Environment and Conservation.

Virginia: 9 VAC 25-260-5 at seq. Water Quality Standards.

Water Use Designations

Park	Site ID	Stream	State	Designated Use
FODO	ICGB	Indian Creek at Grave's Battery	TN	Fish & Aquatic Life
FODO	HSHS	Hickman Spring	TN	Fish & Aquatic Life
SHIL	LDBR	Lower Dill Branch	TN	Fish & Aquatic Life
SHIL	UDBR	Upper Dill Branch	TN	Fish & Aquatic Life
SHIL	SSSS	Shiloh Spring	TN	Fish & Aquatic Life
SHIL	RSRS	Rea Spring	TN	Fish & Aquatic Life
SHIL	SHCR	Shiloh Creek	TN	Fish & Aquatic Life
SHIL	TIBR	Tilgham Branch	TN	Fish & Aquatic Life
SHIL	OWCR	Owl Creek	TN	Fish & Aquatic Life
SHIL	TRTR	Tennessee River	TN	Domestic Water Supply Fish & Aquatic Life Industrial Water Supply Irrigation Livestock Watering & Wildlife Navigation Recreation
STRI	WFMF	West Fork Stones River At McFadden's Ford	TN	Domestic Water Supply Fish & Aquatic Life Industrial Water Supply Irrigation Livestock Watering & Wildlife Recreation
STRI	BSBS	Battlefield Spring	TN	Fish & Aquatic Life
STRI	WFRB	West Fork Stones River At Redoubt Brannon	TN	Domestic Water Supply Fish & Aquatic Life Industrial Water Supply Irrigation Livestock Watering & Wildlife Recreation
STRI	MSMS	Mulch Spring	TN	Fish & Aquatic Life
STRI	REBC	Rebel Yell Cave	TN	Fish & Aquatic Life
STRI	KIPO	King Pond	TN	Fish & Aquatic Life
CHCH	WCHC	West Chickamauga Creek	GA	Secondary Contact Recreation
CHCH	CASP	Cave Spring	GA	Secondary Contact Recreation
CHCH	JASP	Jackson Spring	GA	Secondary Contact Recreation
CHCH	SKSP	Skuka Spring	GA	Secondary Contact Recreation

CHCH	ROSP	Rock Spring	TN	Fish & Aquatic Life
CHCH	GUSP	Gum Spring	TN	Fish & Aquatic Life
CHCH	LOCR	Lookout Creek	TN	Fish & Aquatic Life Industrial Water Supply Irrigation Livestock Watering & Wildlife Recreation
LIRI	CMLR	Canyon Mouth Park, Little River	AL	Outstanding Natural Resource Water
LIRI	JCJC	Johnnie's Creek	AL	Swimming & Water-Body Contact
LIRI	EPLR	Eberhart Point, Little River	AL	Outstanding Natural Resource Water
LIRI	35BR	Highway 35 Bridge, Little River	AL	Outstanding Natural Resource Water
LIRI	YCYC	Yellow Creek	AL	Limited Freshwater Fishery
LIRI	BHLR	Burnt House Ford, Little River	AL	Outstanding Natural Resource Water
LIRI	DPLR	DeSoto State Park, Little River	AL	Outstanding Natural Resource Water
LIRI	DFLR	DeSoto Falls, Little River	AL	Outstanding Natural Resource Water
LIRI	MFLR	Middle Fork, Little River	GA	Secondary Contact Recreation
LIRI	EFLR	East Fork, Little River	GA	Secondary Contact Recreation
RUCA	RUCA	Russell Cave Spring	AL	Outstanding Natural Resource Water
RUCA	RICA	Ridley Cave	AL	Outstanding Natural Resource Water
RUCA	PERC	Picnic Entrance, Russell Cave	AL	Outstanding Natural Resource Water
CARL	TPSP	Trout Pond Spring	NC	HQW
CARL	SILA	Side Lake	NC	Class WS-II
CARL	MORE	Mountain Reservoir	NC	HQW
CARL	FRLA	Front Lake	NC	Class WS-II
NISI	SPBR	Spring Branch	SC	Freshwater
NISI	NICR	Ninety Six Creek	SC	Freshwater
NISI	STFL	Star Fort Lake	SC	Freshwater
COWP	LBIC	Long Branch Island Creek	SC	Freshwater
COWP	LIBC	Little Buck Creek	SC	Freshwater
COPW	SCR2	Suck Creek #2	SC	Freshwater
COPW	SCR3	Suck Creek #3	SC	Freshwater
KIMO	LOBR	Long Branch	SC	Freshwater
KIMO	GRCR	Garner Creek	SC	Freshwater
KIMO	DEBR	Dellingham Branch	SC	Freshwater
KIMO	STCR	Stonehouse Creek	SC	Freshwater
KIMO	KICR	Kings Creek	SC	Freshwater
GUCO	RICR	Richland Creek	NC	Class WS-IV
GUCO	SPRI	Spring	NC	Class WS-IV
ABLI	SISP	Sinking Spring	KY	Coldwater Aquatic Habitat
ABLI	NBKC	North Branch Knob Creek	KY	Warmwater Aquatic Habitat Secondary Contact Recreation
CUGA	LYCU	Little Yellow Creek, upstream	KY	Warmwater Aquatic Habitat Primary Contact Recreation Secondary Contact Recreation
CUGA	DABR	Davis Branch	KY	Warmwater Aquatic Habitat Primary Contact Recreation Secondary Contact Recreation Outstanding State Resource Water
CUGA	LYCD	Little Yellow Creek, downstream	KY	Warmwater Aquatic Habitat Primary Contact Recreation Secondary Contact Recreation
CUGA	TUCR	Tunnel Creek	KY	Warmwater Aquatic Habitat
CUGA	RRCR	Railroad Creek	KY	Warmwater Aquatic Habitat
CUGA	SURU	Sugar Run	KY	Warmwater Aquatic Habitat Primary Contact Recreation Secondary Contact Recreation

CUGA	SHCR	Shillalah Creek	KY	Coldwater Aquatic Habitat Primary Contact Recreation Secondary Contact Recreation
CUGA	GACR	Gap Creek	TN	Fish & Aquatic Life Irrigation Livestock Watering & Wildlife Trout Recreation
CUGA	STCR	Station Creek	VA	Class vi
CUGA	MAFR	Martin Fork	KY	Coldwater Aquatic Habitat Primary Contact Recreation Secondary Contact Recreation Outstanding State Resource Water

Designated Use State-classified

Designated Use not classified by state, classified by CPN WQMP based on State criteria

Budget

The budget section is divided into three sections: Analysis Costs (including all personnel, laboratory and field materials and supplies); Recurring Costs (including annual consumable supplies and materials and maintenance agreements); and a Budget Summary that combines the entire budget together and projects annual operating costs of the CPN WQ Program. Estimates are based upon a round of 14 sample analysis.

Analysis Costs

Personnel

Analysis Type	Prepping bottles	Filtering samples	time required for analysis	reviewing/ entering data
anions	0.75	0.5	3	1
cations	0.75	0.5	3	1
t. metals	0.75	0.5	4	1
pesticides	0.75	0.5	3	1
TOC	1.5	0	2.5	1
Chl-a	0.75	1	3	0.5
TSS	0.75	3	4	0.5
Fecal Coliform	0.75	3	1.5	0.5
Fluorescence	0.75	0	3	1
turbidity	0.75	0	1	0.5
	8.25	9	28	8

Total lab hours per sample event	Max 14 Samples	**53.25**

53.25 hours per sample by a GS9-01 Analysis at an hourly rate of $18.00 yields a total cost of $958.50. Divided by 14 (number of samples in this budget exercise) produces personnel costs of single sample total of $68.46.

Laboratory and field materials and supplies

Analysis	**Supplies needed for analysis**	**Supply per sample**	**Unit**	**Cost of supply**	**subtotal cost**	**Total of each analysis**
anions	vials w/ caps	1.1	ea	$0.60	$0.66	
	0.45 um filters	1.5	ea	$0.30	$0.45	
	5 ml pipette tips	1.1	ea	$0.08	$0.09	
	1 ml pipette tips	1.1	ea	$0.05	$0.06	
	0.100 pipette tips	1.1	ea	$0.05	$0.06	
	gloves	2.2	ea	$0.18	$0.40	
	eluent concentrate	10	ml	$0.25	$2.50	
	labels	1	ea	$0.12	$0.12	
					$4.32	
	Standard	10	ml	$1.85	$18.50	**$5.65**
cations	vials w/ caps	2.1	ea	$0.60	$1.26	
	0.45 um filters	1.5	ea	$0.30	$0.45	
	5 ml pipette tips	2.1	ea	$0.08	$0.17	
	1 ml pipette tips	2.1	ea	$0.05	$0.11	
	0.100 pipette tips	1.5	ea	$0.05	$0.08	
	gloves	2.2	ea	$0.18	$0.40	
	MSA eluent	1	ml	$0.38	$0.38	
	sulfuric acid (preservation)	1	ml	$0.05	$0.05	
	labels	1.1	ea	$0.12	$0.13	
					$3.02	
	Standard	10	ml	$1.85	$18.50	**$4.34**
t. metals	vials w/ caps	1.1	ea	$0.60	$0.66	
	0.45 um filters	1.5	ea	$0.30	$0.45	
	5 ml pipette tips	1.1	ea	$0.08	$0.09	
	1 ml pipette tips	1.1	ea	$0.05	$0.06	
	0.100 pipette tips	1.1	ea	$0.05	$0.06	
	gloves	2.2	ea	$0.18	$0.40	
	eluent	10	ml	$0.08	$0.80	
	post column eluent	20	ml	$0.05	$1.00	
	nitric acid (preservation)	1	ml	$0.05	$0.05	
	labels	1.1	ea	$0.12	$0.13	
					$3.69	
	Standard	10	ml	$2.79	$27.90	**$5.68**
pesticides	vials w/ caps	1.1	ea	$0.60	$0.66	
	0.45 um filters	1.5	ea	$0.30	$0.45	
	5 ml pipette tips	1.1	ea	$0.08	$0.09	
	1 ml pipette tips	1.1	ea	$0.05	$0.06	
	0.100 pipette tips	1.1	ea	$0.05	$0.06	
	gloves	2.2	ea	$0.18	$0.40	
	eluent	1	ml	$0.10	$0.10	
	labels	1.1	ea	$0.12	$0.13	
					$1.94	
	Standard	1	ml	$2.00	$2.00	**$2.08**

Analysis	**Supplies needed for analysis**	**Supply per sample**	**Unit**	**Cost of supply**	**subtotal cost**	**Total of each analysis**
TOC	Aluminum foil	0.5	sq ft	$0.05	$0.03	
	septa	1	ea	$0.40	$0.40	
	HCl	1	ml	$0.02	$0.02	
	gloves	2	ea	$0.18	$0.36	
	labels	1	ea	$0.12	$0.12	
					$0.93	
	TOC standard Kit	1	bottle	$0.76	$0.76	**$0.98**
Chl-a	glass fiber filters	1.1	ea	$0.92	$1.01	
	petri dishes	1.1	ea	$0.31	$0.34	
	aluminum foil	0.5	sq ft	$0.05	$0.03	
	acetone to sterize equip.	75	ml	$0.03	$2.25	
	cuvettes	1.1	ea	$0.15	$0.17	
	gloves	2.2	ea	$0.18	$0.40	
	labels	1.1	ea	$0.12	$0.13	
					$4.32	
	standard	1	ml	$0.86	$0.86	**$4.38**
TSS	aluminum weight dish	1.1	ea	$0.30	$0.33	
	glass fiber filter	2.2	ea	$0.92	$2.02	
	gloves	2.2	ea	$0.18	$0.40	
	labels	1.1	ea	$0.12	$0.13	
					subtotal	**$2.88**
Fecal Coliform	petri dish w/ absorb. pad	3.1	ea	$0.40	$1.24	
	0.45 um filters	3.1	ea	$0.40	$1.24	
	media, m-FC	3.1	ampules	$0.85	$2.64	
	disposable 60 ml syringes	1.1	ea	$1.25	$1.38	
	acetone	1	ml	$0.30	$0.30	
	gloves	2.2	ea	$0.18	$0.40	
	Whirlpak	1.1	ea	$0.14	$0.15	
					subtotal	**$7.34**
Fluorescenc	cuvette	1.1	ea	$0.15	$0.17	
	gloves	2.2	ea	$0.18	$0.40	
	labels	1.1	ea	$0.12	$0.13	
					subtotal	**$0.69**
turbidity	gloves	2.2	ea	$0.18	$0.40	
					subtotal	**$0.40**
Total Lab cost per sampling event						**$38.21**

Field Costs						
field pH	field 4 pH cal. Pack	1	ea	$0.95	$0.95	
	field 7 pH cal. Pack	1	ea	$0.95	$0.95	
	field 10 pH cal. Pack	1	ea	$0.95	$0.95	
field SPC	conductivity calibration pack	1	ea	$0.95	$0.95	
Total Field costs per sampling event					**$3.80**	**$0.27**

Grand total of Lab and Field costs per sample	**$38.48**
Personnel costs per sample	**$68.46**
Grand Total Cost per sample	**$106.95**

Recurring Costs

Annual Supplies needed	Quantity of Supply per year	Unit	Unit Cost of supply	cost	subtotals	total
IC instrument						
helium for IC	2	bottle	$410.00	$820.00		
lease agreement for Helium	1	ea	$65.50	$65.50		
anion column	1	ea	$750.00	$750.00		
anion guard	1	ea	$235.00	$235.00		
anion suppressor	1	ea	$885.00	$885.00		
cation column	1	ea	$750.00	$750.00		
cation guard	1	ea	$235.00	$235.00		
cation suppressor	1	ea	$885.00	$885.00		
t. metals guard	1	ea	$720.00	$720.00		
t. metals column	1	ea	$205.00	$205.00		
pesticides column	1	ea	$700.00	$700.00		
pesticides guard	1	ea	$210.00	$210.00		
IC spare parts kit	1	kit	$1,000.00	$1,000.00		
other spare/replacemnt parts	1	ea	$1,000.00	$1,000.00		
					$8,460.50	
proficiency testing supplies						
TOC test	1	ea	$50.00	$50.00		
TOC QC	1	ea	$46.00	$46.00		
anion PE sample	1	ea	$75.00	$75.00		
nutrients QC sample	1	ea	$60.00	$60.00		
minerals PE testing	1	ea	$75.00	$75.00		
minerals QC testing	1	ea	$67.00	$67.00		
bromide PE	1	ea	$70.00	$70.00		
bromide QC	1	ea	$70.00	$70.00		
					$513.00	
TOC						
TOC spare parts kit	1	kit	$675.00	$675.00		
ultra pure air for TOC	2	bottle	$500.00	$1,000.00		
lease agreement for air	1	ea	$65.50	$65.50		
Catalyst - normal	1	ea	$110.00	$110.00		
halogen scrubber	2	ea	$95.00	$190.00		
filters	1	ea	$35.00	$35.00		
CO2 scrubber	1	ea	$53.00	$53.00		
					$2,128.50	
Nanopure						
nanopure filter carts	2	set	$500.00	$1,000.00		
nanopure sanitizing solution	2	ea	$25.00	$50.00		
final filter bulbs	2	ea	$55.00	$110.00		
Liquidnox for cleaning bottles	2	bottles	$6.95	$13.90		
					$1,173.90	
Grease pens	1	pk	$15.00	$15.00		
bench top pH replace probe	1	ea	$285.00	$285.00		

electrode storage solution	1 ea	$11.00	$11.00		
electrode cleaning solution	1 ea	$8.00	$8.00		
DO probe replacement probe	2 ea	$320.00	$640.00		
replacement electrolyte sol.	2 500 ml	$15.00	$30.00		
replacement membrane	2 ea	$42.00	$84.00		
pH/ Conductivity replace probe	2 ea	$140.00	$280.00		
tubing	3 box of 25 feet	$85.70	$257.10		
starter for fecal incubators	4 ea	$1.11	$4.44		
KCl for laptop pH probe	1 bottles	$100.00	$100.00		
				$1,714.54	
					$13,990.44
IC maintenance agreement	1 ea	$7,500.00	$7,500.00		
Spect maintenance agreement	1 ea	$2,026.00	$2,026.00		
TOC maintenance agreement	1 ea	$3,275.00	$3,275.00		
					$12,801.00
Total Recurring Costs					**$26,791.44**

Budget Summary
Per Year WQ Lab Estimates

Based upon the budget tables above, each sample will cost $107, including all laboratory materials and supplies, and personnel time. This will be known as *analysis costs*. Total analysis costs are determined by multiplying $107 by the number of samples per year.

There are a number of expenses, including annual consumable supplies and materials and maintenance agreements that will be known as *recurring costs*. Recurring costs are based on estimates of $13,990 for annual consumables and $12,800 for maintenance agreements, for a total of $26,790 per year.

MACA samples (its WQ program runs separate from the CPN WQ program) are included in this estimate in order to determine the percentage of MACA samples of the total samples being run by the lab in one year. This way the CPN will only be responsible for covering the analysis and recurring costs for CPN samples. For example, in FY03 there will be a grand total of 416 samples processed. Of that, 168, or 40% will be generated by the MACA WQ program. Hence, MACA will be responsible for covering 40% of the analysis and recurring costs, or $28,787 for FY03.

For CPN parks proximal to MACA, MACA field personnel will perform sample collection. The rate estimates for MACA field personnel are based on 10-hour days at a GS 9-1 rate of $18.00/hour. These costs are added to CPN's portion of analysis and recurring sample costs. In the FY03 example, the CPN will be responsible for 60% (since 60% of FY03 samples will be generated by CPN parks) of the analysis and recurring costs, or $42,495, plus $2,160 to cover MACA field personnel expenses.

These estimates to do include annual inflation rates, nor do they reflect the costs of sample shipment.

FY03	*Samples*		*Subtotals*	*Totals*
Analysis Costs ($107/sample)	416 total			44,500
Recurring Costs				26,790
				71,290
MACA	168	(40%)	28,520	**28,520**
CPN	248	(60%)	42,770	42,770
MACA Field Personnel	120 hours		2,160	2,160
CPN Total FY03				**44,930**

FY04	*Samples*		*Subtotals*	*Totals*
Analysis Costs ($107/sample)	394 total			42,140
Recurring Costs				26,790
				68,930
MACA	168	(43%)	29,640	**29,640**
CPN	226	(57%)	39,290	39,290
MACA Field Personnel	220 hours		3,960	3,960
CPN Total FY04				**43,250**

FY05	*Samples*		*Subtotals*	*Totals*
Analysis Costs ($107/sample)	392 total			42,140
Recurring Costs				26,790
				68,930
MACA	168	(43%)	29,640	**29,640**
CPN	224	(57%)	39,290	39,290
MACA Field Personnel	0 hours		0	0
CPN Total FY05				**39,290**

FY06	*Samples*		*Subtotals*	*Totals*
Analysis Costs ($107/sample)	370 total			39,590
Recurring Costs				26,790
				66,380
MACA	168	(45%)	29,870	**29,870**
CPN	202	(55%)	36,510	36,510
MACA Field Personnel	60 hours		1,080	1,080
CPN Total FY06				**37,590**

FY07	*Samples*		*Subtotals*	*Totals*
Analysis Costs ($107/sample)	500 total			54,570
Recurring Costs				26,790
				81,360
MACA	168	(34%)	27,660	**27,660**
CPN	332	(66%)	53,700	53,700
MACA Field Personnel	240 hours		4,320	4,320
CPN Total FY07				**58,020**

FY08	*Samples*		*Subtotals*	*Totals*
Analysis Costs ($107/sample)	478 total			51,150
Recurring Costs				26,790
				77,940
MACA	168	(35%)	27,280	**27,280**
CPN	310	(65%)	50,660	50,660
MACA Field Personnel	340 hours		6,120	6,120
CPN Total FY08				**56,780**

Appendix A

Data of Recent/Ongoing Studies, not yet entered in STORET

Fort Donelson National Battlefield

Date	Location	Parameter	Result	Unit
11-23-98	Cumberland River	Chlorophyll A		mg/m^3
11-23-98	Cumberland River	Temperature	19	C
11-23-98	Cumberland River	pH	8.1	SU
11-23-98	Cumberland River	Alkalinity	72	mg/l
11-23-98	Cumberland River	Dissolved O_2	10.0	mg/l
11-23-98	Cumberland River	Dissolved Solids	140	mg/l
11-23-98	Cumberland River	Fecal Coliform	<10	Col/100 ml
11-23-98	Cumberland River	Nitrate	<.40	mg/l
11-23-98	Cumberland River	Orthophosphate	.059	mg/l
11-23-98	Cumberland River	Specific Conductance	210	µS
11-23-98	Cumberland River	Sulfate	25	mg/l
11-23-98	Cumberland River	Turbidity	6.07	NTU
1-26-99	Cumberland River	Chlorophyll A	26.7	mg/m^3
1-26-99	Cumberland River	Temperature	13	C
1-26-99	Cumberland River	pH	8.1	SU
1-26-99	Cumberland River	Alkalinity	72	mg/l
1-26-99	Cumberland River	Dissolved O_2	10.2	mg/l
1-26-99	Cumberland River	Dissolved Solids	150	mg/l
1-26-99	Cumberland River	Fecal Coliform	>5,000	Col/100 ml
1-26-99	Cumberland River	Nitrate	1.2	mg/l
1-26-99	Cumberland River	Orthophosphate	3.7	mg/l
1-26-99	Cumberland River	Specific Conductance	189	µS
1-26-99	Cumberland River	Sulfate	12	mg/l
1-26-99	Cumberland River	Turbidity	1,210	NTU
5-25-99	Cumberland River	Chlorophyll A	2.03	mg/m^3
5-25-99	Cumberland River	Temperature	24	C
5-25-99	Cumberland River	pH	8.3	SU
5-25-99	Cumberland River	Alkalinity	91	mg/l
5-25-99	Cumberland River	Dissolved O_2	9.8	mg/l
5-25-99	Cumberland River	Dissolved Solids	140	mg/l
5-25-99	Cumberland River	Fecal Coliform	10	Col/100 ml
5-25-99	Cumberland River	Nitrate	.60	mg/l
5-25-99	Cumberland River	Orthophosphate	.062	mg/l
5-25-99	Cumberland River	Specific Conductance	240	µS
5-25-99	Cumberland River	Sulfate	20	mg/l
5-25-99	Cumberland River	Turbidity	8.08	NTU
11-23-98	Indian Creek	Chlorophyll A		mg/m^3
11-23-98	Indian Creek	Temperature	15	C
11-23-98	Indian Creek	pH	8.3	SU
11-23-98	Indian Creek	Alkalinity	180	mg/l
11-23-98	Indian Creek	Dissolved O_2	9.6	mg/l

11-23-98	Indian Creek	Dissolved Solids	200	mg/l
11-23-98	Indian Creek	Fecal Coliform	30	Col/100 ml
11-23-98	Indian Creek	Nitrate	.26	mg/l
11-23-98	Indian Creek	Orthophosphate	<.025	mg/l
11-23-98	Indian Creek	Specific Conductance	300	µS
11-23-98	Indian Creek	Sulfate	<10	mg/l
11-23-98	Indian Creek	Turbidity	1.67	NTU
1-26-99	Indian Creek	Chlorophyll A	9.31	mg/m^3
1-26-99	Indian Creek	Temperature	12	C
1-26-99	Indian Creek	pH	8.1	SU
1-26-99	Indian Creek	Alkalinity	87	mg/l
1-26-99	Indian Creek	Dissolved O_2	9.9	mg/l
1-26-99	Indian Creek	Dissolved Solids	130	mg/l
1-26-99	Indian Creek	Fecal Coliform	36	Col/100 ml
1-26-99	Indian Creek	Nitrate	.65	mg/l
1-26-99	Indian Creek	Orthophosphate	.043	mg/l
1-26-99	Indian Creek	Specific Conductance	187	µS
1-26-99	Indian Creek	Sulfate	<10	mg/l
1-26-99	Indian Creek	Turbidity	8.17	NTU
5-25-99	Indian Creek	Chlorophyll A	<.50	mg/m^3
5-25-99	Indian Creek	Temperature	17	C
5-25-99	Indian Creek	pH	7.2	SU
5-25-99	Indian Creek	Alkalinity	150	mg/l
5-25-99	Indian Creek	Dissolved O_2	9.6	mg/l
5-25-99	Indian Creek	Dissolved Solids	190	mg/l
5-25-99	Indian Creek	Fecal Coliform	114	Col/100 ml
5-25-99	Indian Creek	Nitrate	<.40	mg/l
5-25-99	Indian Creek	Orthophosphate	.031	mg/l
5-25-99	Indian Creek	Specific Conductance	320	µS
5-25-99	Indian Creek	Sulfate	<5	mg/l
5-25-99	Indian Creek	Turbidity	1.5	NTU
11-23-98	Indian Bay	Chlorophyll A		mg/m^3
11-23-98	Indian Bay	Temperature	17	C
11-23-98	Indian Bay	pH	8.0	SU
11-23-98	Indian Bay	Alkalinity	100	mg/l
11-23-98	Indian Bay	Dissolved O_2	11.1	mg/l
11-23-98	Indian Bay	Dissolved Solids	160	mg/l
11-23-98	Indian Bay	Fecal Coliform	<10	Col/100 ml
11-23-98	Indian Bay	Nitrate	<.40	mg/l
11-23-98	Indian Bay	Orthophosphate	.050	mg/l
11-23-98	Indian Bay	Specific Conductance	240	µS
11-23-98	Indian Bay	Sulfate	20	mg/l
11-23-98	Indian Bay	Turbidity	16.8	NTU
1-26-99	Indian Bay	Chlorophyll A	4.67	mg/m^3
1-26-99	Indian Bay	Temperature	13	C

1-26-99	Indian Bay	pH	8.0	SU
1-26-99	Indian Bay	Alkalinity	55	mg/l
1-26-99	Indian Bay	Dissolved O_2	10.5	mg/l
1-26-99	Indian Bay	Dissolved Solids	120	mg/l
1-26-99	Indian Bay	Fecal Coliform	880	Col/100 ml
1-26-99	Indian Bay	Nitrate	.85	mg/l
1-26-99	Indian Bay	Orthophosphate	.36	mg/l
1-26-99	Indian Bay	Specific Conductance	145	μS
1-26-99	Indian Bay	Sulfate	<10	mg/l
1-26-99	Indian Bay	Turbidity	76	NTU
5-25-99	Indian Bay	Chlorophyll A	8.52	mg/m^3
5-25-99	Indian Bay	Temperature	23	C
5-25-99	Indian Bay	pH	8.1	SU
5-25-99	Indian Bay	Alkalinity	99	mg/l
5-25-99	Indian Bay	Dissolved O_2	9.8	mg/l
5-25-99	Indian Bay	Dissolved Solids	150	mg/l
5-25-99	Indian Bay	Fecal Coliform	<2	Col/100 ml
5-25-99	Indian Bay	Nitrate	<.40	mg/l
5-25-99	Indian Bay	Orthophosphate	.039	mg/l
5-25-99	Indian Bay	Specific Conductance	240	μS
5-25-99	Indian Bay	Sulfate	14	mg/l
5-25-99	Indian Bay	Turbidity	10	NTU
11-23-98	Hickman Bay	Chlorophyll A		mg/m^3
11-23-98	Hickman Bay	Temperature	16	C
11-23-98	Hickman Bay	pH	8.4	SU
11-23-98	Hickman Bay	Alkalinity	86	mg/l
11-23-98	Hickman Bay	Dissolved O_2	10.8	mg/l
11-23-98	Hickman Bay	Dissolved Solids	140	mg/l
11-23-98	Hickman Bay	Fecal Coliform	<10	Col/100 ml
11-23-98	Hickman Bay	Nitrate	<.40	mg/l
11-23-98	Hickman Bay	Orthophosphate	<.025	mg/l
11-23-98	Hickman Bay	Specific Conductance	220	μS
11-23-98	Hickman Bay	Sulfate	22	mg/l
11-23-98	Hickman Bay	Turbidity	11.7	NTU
1-26-99	Hickman Bay	Chlorophyll A	4.81	mg/m^3
1-26-99	Hickman Bay	Temperature	13	C
1-26-99	Hickman Bay	pH	8.1	SU
1-26-99	Hickman Bay	Alkalinity	38	mg/l
1-26-99	Hickman Bay	Dissolved O_2	10.7	mg/l
1-26-99	Hickman Bay	Dissolved Solids	110	mg/l
1-26-99	Hickman Bay	Fecal Coliform	>3,000	Col/100 ml
1-26-99	Hickman Bay	Nitrate	.64	mg/l
1-26-99	Hickman Bay	Orthophosphate	.38	mg/l
1-26-99	Hickman Bay	Specific Conductance	108	μS
1-26-99	Hickman Bay	Sulfate	<10	mg/l

1-26-99	Hickman Bay	Turbidity	96.5	NTU
5-25-99	Hickman Bay	Chlorophyll A	17.1	mg/m^3
5-25-99	Hickman Bay	Temperature	24	C
5-25-99	Hickman Bay	pH	8.0	SU
5-25-99	Hickman Bay	Alkalinity	99	mg/l
5-25-99	Hickman Bay	Dissolved O_2	9.7	mg/l
5-25-99	Hickman Bay	Dissolved Solids	150	mg/l
5-25-99	Hickman Bay	Fecal Coliform	4	Col/100 ml
5-25-99	Hickman Bay	Nitrate	<.40	mg/l
5-25-99	Hickman Bay	Orthophosphate	.026	mg/l
5-25-99	Hickman Bay	Specific Conductance	230	µS
5-25-99	Hickman Bay	Sulfate	14	mg/l
5-25-99	Hickman Bay	Turbidity	13.6	NTU
11-23-98	Hickman Spring	Chlorophyll A		mg/m^3
11-23-98	Hickman Spring	Temperature	18	C
11-23-98	Hickman Spring	pH	7.7	SU
11-23-98	Hickman Spring	Alkalinity	190	mg/l
11-23-98	Hickman Spring	Dissolved O_2	9.7	mg/l
11-23-98	Hickman Spring	Dissolved Solids	220	mg/l
11-23-98	Hickman Spring	Fecal Coliform	50	Col/100 ml
11-23-98	Hickman Spring	Nitrate	<.40	mg/l
11-23-98	Hickman Spring	Orthophosphate	.033	mg/l
11-23-98	Hickman Spring	Specific Conductance	340	µS
11-23-98	Hickman Spring	Sulfate	<10	mg/l
11-23-98	Hickman Spring	Turbidity	17.8	NTU
1-26-99	Hickman Spring	Chlorophyll A	0	mg/m^3
1-26-99	Hickman Spring	Temperature	15	C
1-26-99	Hickman Spring	pH	7.7	SU
1-26-99	Hickman Spring	Alkalinity	180	mg/l
1-26-99	Hickman Spring	Dissolved O_2	9.9	mg/l
1-26-99	Hickman Spring	Dissolved Solids	230	mg/l
1-26-99	Hickman Spring	Fecal Coliform	5	Col/100 ml
1-26-99	Hickman Spring	Nitrate	.51	mg/l
1-26-99	Hickman Spring	Orthophosphate	.025	mg/l
1-26-99	Hickman Spring	Specific Conductance	339	µS
1-26-99	Hickman Spring	Sulfate	<10	mg/l
1-26-99	Hickman Spring	Turbidity	4.15	NTU
5-25-99	Hickman Spring	Chlorophyll A	1.24	mg/m^3
5-25-99	Hickman Spring	Temperature	18	C
5-25-99	Hickman Spring	pH	7.6	SU
5-25-99	Hickman Spring	Alkalinity	230	mg/l
5-25-99	Hickman Spring	Dissolved O_2	9.7	mg/l
5-25-99	Hickman Spring	Dissolved Solids	260	mg/l
5-25-99	Hickman Spring	Fecal Coliform	4	Col/100 ml
5-25-99	Hickman Spring	Nitrate	<.40	mg/l

5-25-99	Hickman Spring	Orthophosphate	.056	mg/l
5-25-99	Hickman Spring	Specific Conductance	420	μS
5-25-99	Hickman Spring	Sulfate	<5	mg/l
5-25-99	Hickman Spring	Turbidity	17.4	NTU

Shiloh National Battlefield

Source: Dr. Jack Grubaugh, University of Memphis

Worksheet	Parameter
pH	pH
DO	Dissolved oxygen
TEMP	Temperature
VEL	Surface current velocity
COND	Conductivity
NO3	Nitrate concentration
PO4	Phosphate concentration
TURB	Turbidity
TSS	Total suspended solids
HARD	Hardness
ALK	Alkalinity

Site Code	Site	Latitude	Longitude
UDB	Upper Dill Branch	N35 08.717'	W88 19.541'
LDB	Lower Dill Branch	N35 08.680'	W88 19.206'
SHB	Shiloh Branch	N35 07.830'	W88 21.648'
TLB	Tilghman Branch	N35 09.121'	W88 20.517'
TNR	Tennessee River		

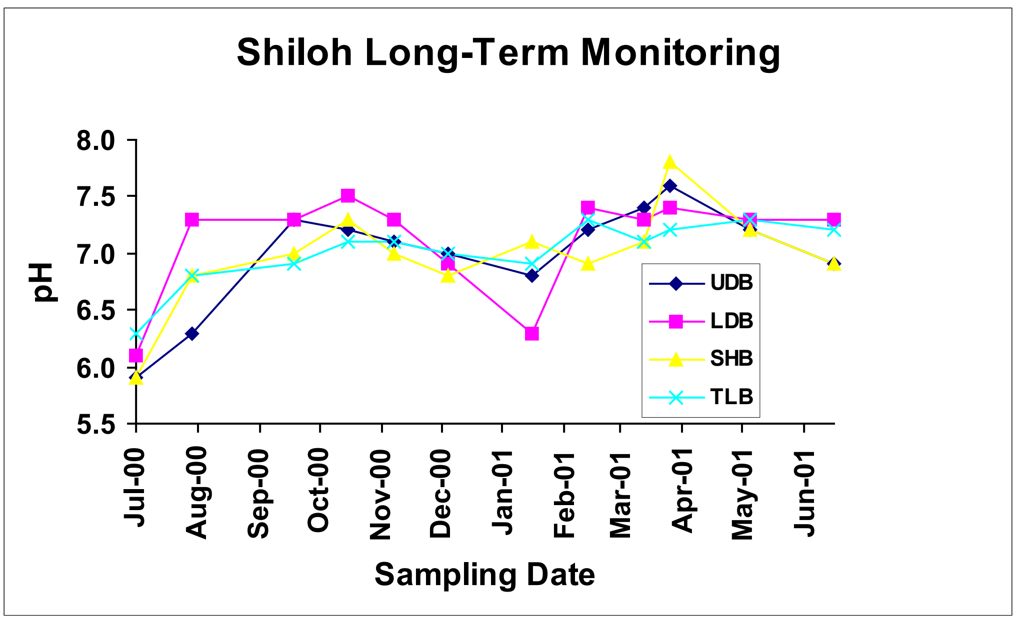
Other

1 Record to date from July, 2000, to June, 2001.
2 Miscellaneous comments are in column G on worksheets.
3 VEL and TSS not determined on a monthly basis.
4 TURB, HARD, and ALK measures started in Oct, 2000.

pH data

Data are reported in standard pH units.

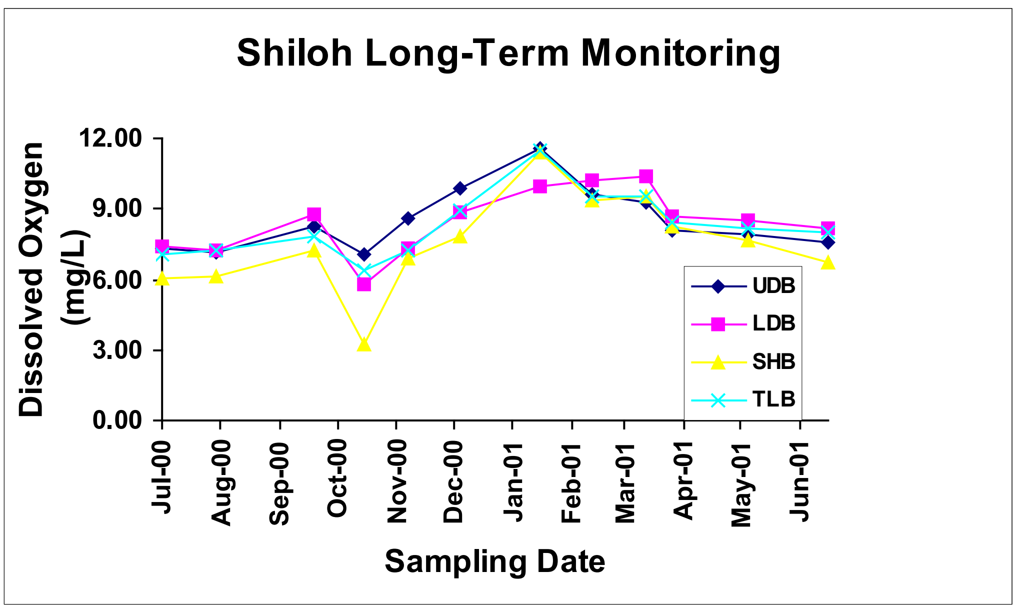
Date	UDB	LDB	SHB	TLB
12-Jul-00	5.9	6.1	5.9	6.3
9-Aug-00	6.3	7.3	6.8	6.8
29-Sep-00	7.3	7.3	7.0	6.9
26-Oct-00	7.2	7.5	7.3	7.1
18-Nov-00	7.1	7.3	7.0	7.1
15-Dec-00	7.0	6.9	6.8	7.0
26-Jan-01	6.8	6.3	7.1	6.9
23-Feb-01	7.2	7.4	6.9	7.3
23-Mar-01	7.4	7.3	7.1	7.1
5-Apr-01	7.6	7.4	7.8	7.2
15-May-01	7.2	7.3	7.2	7.3
26-Jun-01	6.9	7.3	6.9	7.2



Dissolved Oxygen data

Data are reported as mg/L

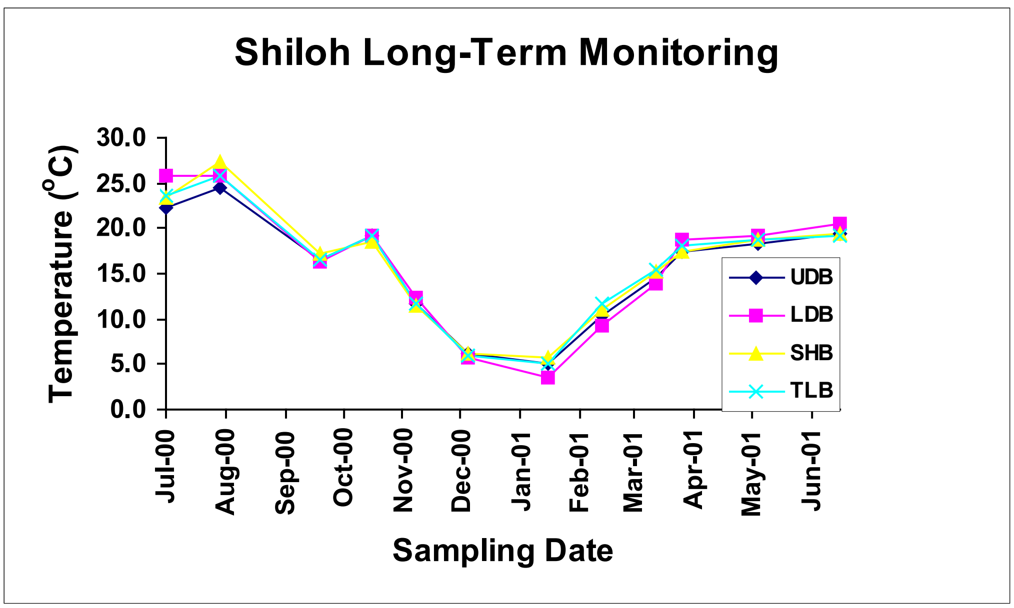
Date	UDB	LDB	SHB	TLB	
12-Jul-00	7.32	7.44	6.02	7.04	
9-Aug-00	7.17	7.25	6.16	7.26	
29-Sep-00	8.26	8.76	7.23	7.83	
26-Oct-00	7.10	5.82	3.25	6.40	SHB reading was rechecked
18-Nov-00	8.61	7.34	6.93	7.21	
15-Dec-00	9.87	8.86	7.86	8.91	
26-Jan-01	11.54	9.95	11.37	11.46	
23-Feb-01	9.61	10.18	9.35	9.51	
23-Mar-01	9.31	10.35	9.55	9.50	
5-Apr-01	8.05	8.65	8.27	8.39	
15-May-01	7.89	8.47	7.65	8.18	
26-Jun-01	7.60	8.18	6.70	7.99	



Temperature Data

Data are reported as C

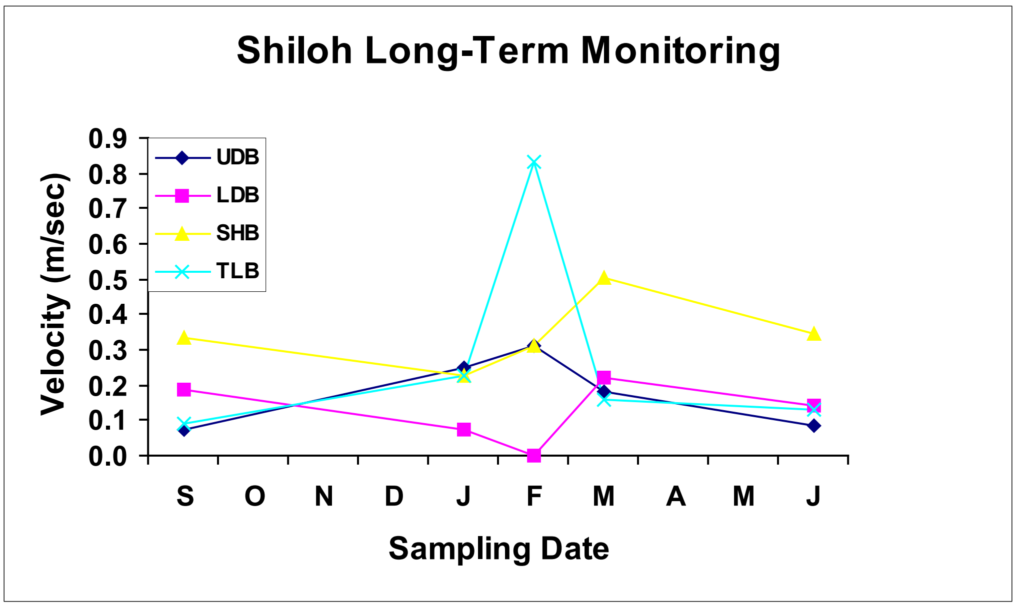
Date	UDB	LDB	SHB	TLB
12-Jul-00	22.3	25.7	23.3	23.6
9-Aug-00	24.5	25.7	27.3	25.7
29-Sep-00	16.6	16.4	17.1	16.6
26-Oct-00	19.3	19.1	18.6	19.1
18-Nov-00	11.6	12.3	11.5	11.6
15-Dec-00	6.2	5.8	6.1	6.0
26-Jan-01	5.0	3.6	5.7	5.1
23-Feb-01	10.3	9.3	11.1	11.6
23-Mar-01	14.6	13.9	15.3	15.5
5-Apr-01	17.5	18.7	17.4	18.0
15-May-01	18.2	19.3	18.7	18.7
26-Jun-01	19.4	20.5	19.5	19.3



Velocity data

Data are reported as m/sec

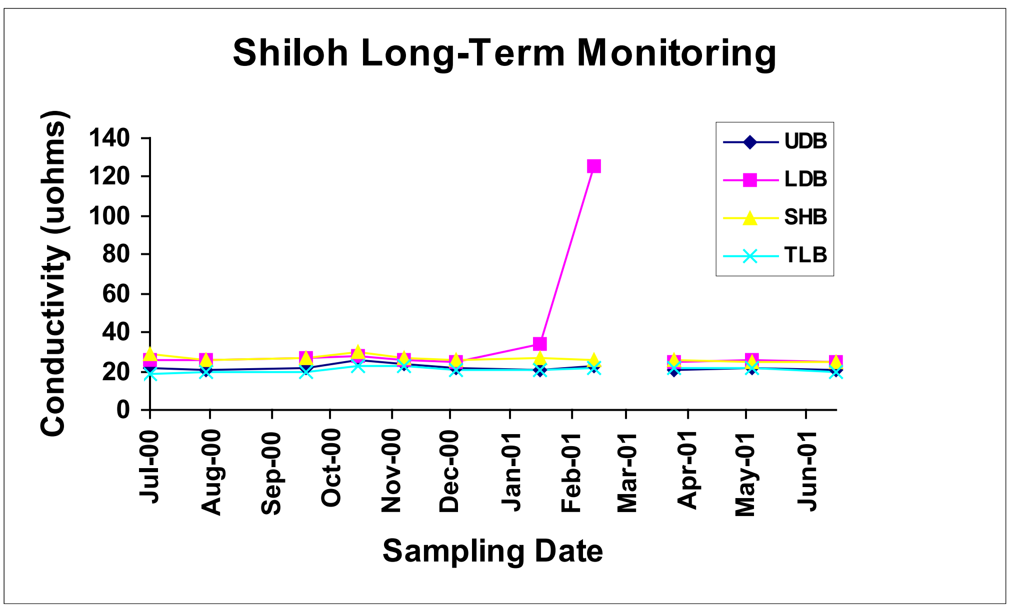
Date	UDB	LDB	SHB	TLB	
29-Sep-00	0.07	0.19	0.33	0.09	
26-Jan-01	0.25	0.07	0.23	0.23	
23-Feb-01	0.31	0.00	0.31	0.83	Backwater effect at LDB from TNR
23-Mar-01	0.18	0.22	0.50	0.16	
26-Jun-01	0.08	0.14	0.35	0.13	



Specific conductivity data

Data are reported as microhms

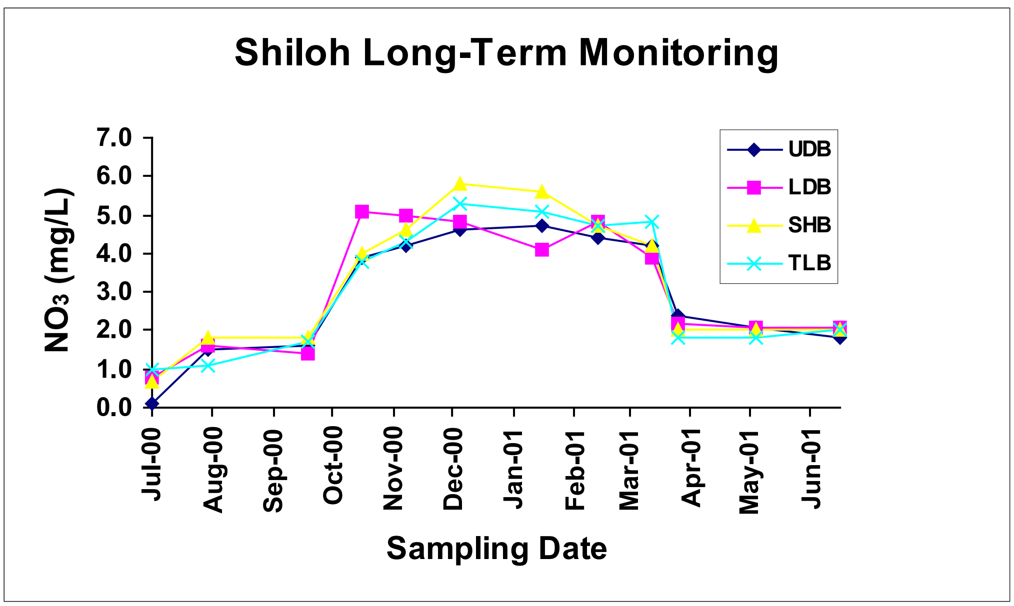
Date	UDB	LDB	SHB	TLB	
12-Jul-00	21.6	25.3	28.5	18.1	
9-Aug-00	20.1	26.2	26.2	19.7	
29-Sep-00	21.7	26.4	27.2	19.8	
26-Oct-00	25.5	28.2	30.2	22.7	
18-Nov-00	23.6	26.1	26.3	22.3	
15-Dec-00	21.2	24.3	25.9	20.2	
26-Jan-01	20.7	33.8	27.2	21	
23-Feb-01	22.2	125.2	25.6	21.5	Backwater effect at LDB from TNR
23-Mar-01					Meter malfunction.
5-Apr-01	20.7	25	25.4	21.9	
15-May-01	21.2	26.2	24.8	21.6	
26-Jun-01	20.5	24.3	25.1	19.1	



Nitrate data

Data are reported as mg/L

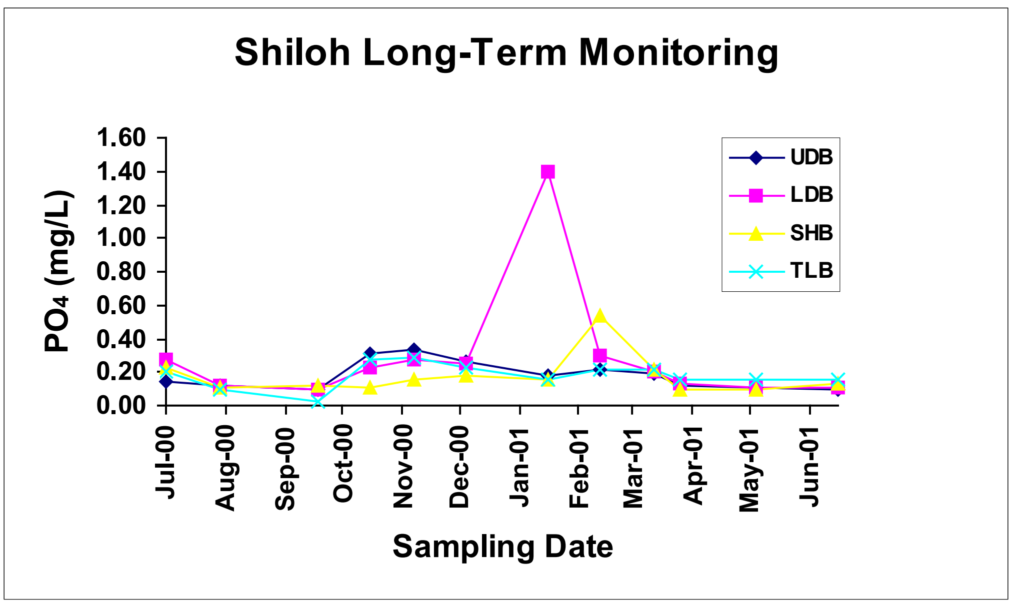
Date	UDB	LDB	SHB	TLB
12-Jul-00	0.1	0.8	0.7	1.0
9-Aug-00	1.5	1.6	1.8	1.1
29-Sep-00	1.6	1.4	1.8	1.7
26-Oct-00	3.9	5.1	4.0	3.8
18-Nov-00	4.2	5.0	4.6	4.3
15-Dec-00	4.6	4.8	5.8	5.3
26-Jan-01	4.7	4.1	5.6	5.1
23-Feb-01	4.4	4.8	4.7	4.7
23-Mar-01	4.2	3.9	4.2	4.8
5-Apr-01	2.4	2.2	2.0	1.8
15-May-01	2.1	2.1	2.0	1.8
26-Jun-01	1.8	2.1	2.0	2.0



Phosphorous data

Data are reported as mg/L

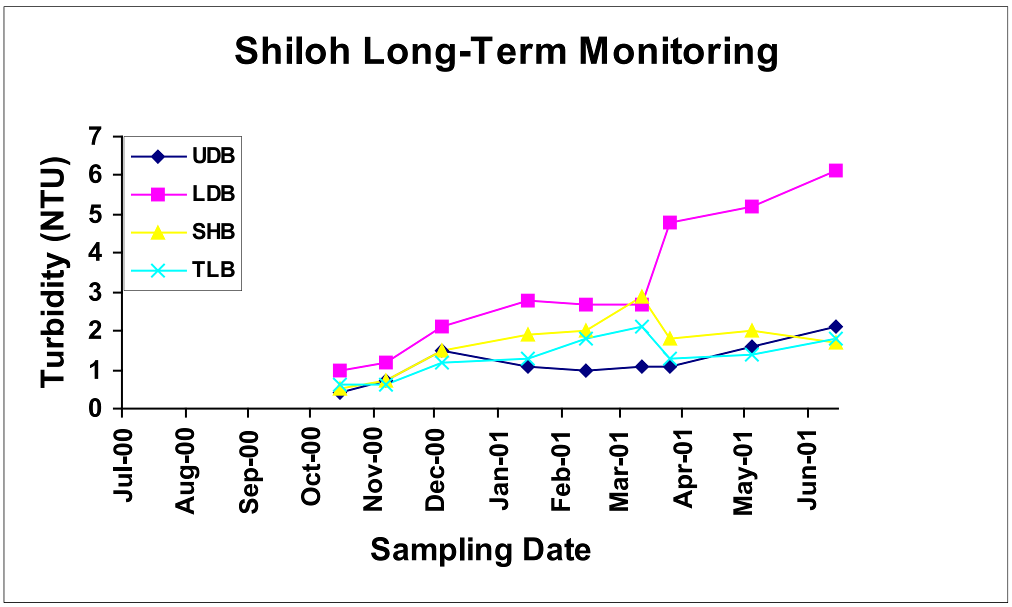
Date	UDB	LDB	SHB	TLB
12-Jul-00	0.14	0.28	0.23	0.20
9-Aug-00	0.12	0.12	0.11	0.09
29-Sep-00	0.09	0.09	0.12	0.02
26-Oct-00	0.31	0.23	0.11	0.27
18-Nov-00	0.33	0.28	0.15	0.29
15-Dec-00	0.26	0.25	0.18	0.23
26-Jan-01	0.18	1.40	0.16	0.16
23-Feb-01	0.22	0.30	0.54	0.22
23-Mar-01	0.19	0.20	0.22	0.21
5-Apr-01	0.12	0.13	0.10	0.16
15-May-01	0.11	0.11	0.10	0.15
26-Jun-01	0.09	0.11	0.13	0.15



Turbidity data

Data are reported as NTU

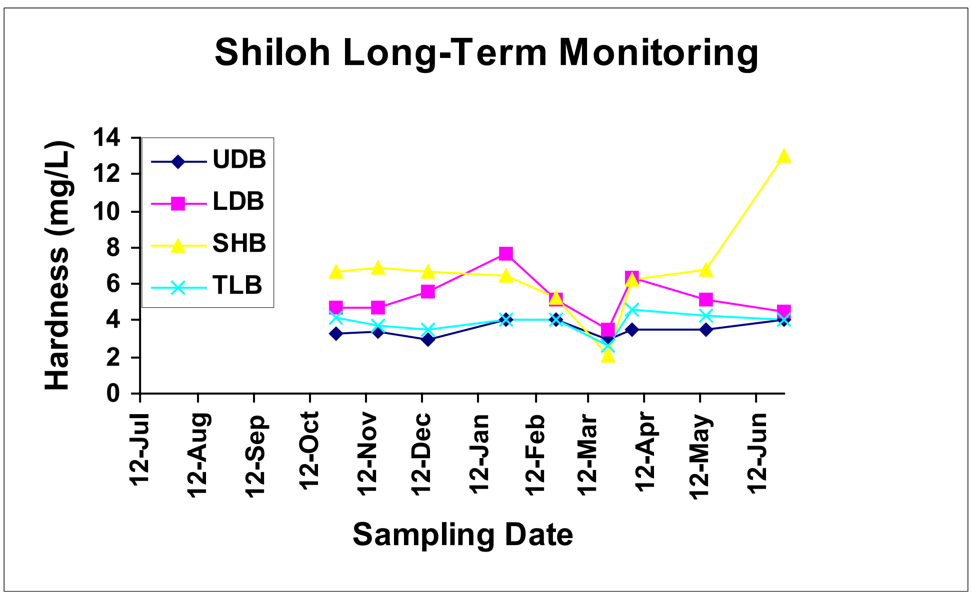
Date	UDB	LDB	SHB	TLB
12-Jul-00				
9-Aug-00				
29-Sep-00				
26-Oct-00	0.4	1.0	0.5	0.6
18-Nov-00	0.7	1.2	0.7	0.6
15-Dec-00	1.5	2.1	1.5	1.2
26-Jan-01	1.1	2.8	1.9	1.3
23-Feb-01	1.0	2.7	2.0	1.8
23-Mar-01	1.1	2.7	2.9	2.1
5-Apr-01	1.1	4.8	1.8	1.3
15-May-01	1.6	5.2	2.0	1.4
26-Jun-01	2.1	6.1	1.7	1.8



Hardness data

Data are reported as mg/L Ca and MgCO3

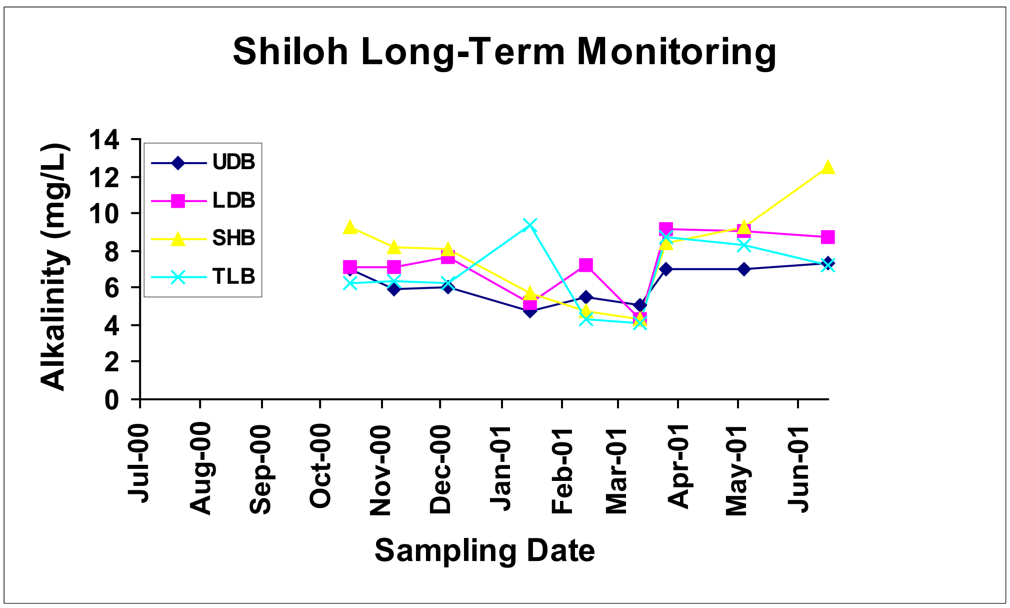
Date	UDB	LDB	SHB	TLB
12-Jul-00				
9-Aug-00				
29-Sep-00				
26-Oct-00	3.3	4.7	6.7	4.2
18-Nov-00	3.4	4.7	6.9	3.7
15-Dec-00	3.0	5.6	6.7	3.5
26-Jan-01	4.0	7.7	6.4	4.0
23-Feb-01	4.0	5.1	5.2	4.1
23-Mar-01	3.0	3.5	2.1	2.6
5-Apr-01	3.5	6.3	6.2	4.6
15-May-01	3.5	5.1	6.8	4.3
26-Jun-01	4.0	4.5	13.0	4.0



Alkalinity data

Data are reported as mg/L CaCO3

Date	UDB	LDB	SHB	TLB
12-Jul-00				
9-Aug-00				
29-Sep-00				
26-Oct-00	7.0	7.1	9.3	6.3
18-Nov-00	5.9	7.1	8.2	6.4
15-Dec-00	6.0	7.6	8.1	6.3
26-Jan-01	4.7	5.2	5.7	9.4
23-Feb-01	5.5	7.2	4.7	4.3
23-Mar-01	5.1	4.3	4.3	4.1
5-Apr-01	7.0	9.2	8.4	8.7
15-May-01	7.0	9.1	9.3	8.3
26-Jun-01	7.3	8.7	12.5	7.2



Total suspended solids data

Reported as mg/L

Date	UDB	LDB	SHB	TLB
5-Apr-01	17.8	17.3	2.2	40.0
26-Jun-01	9.2	21.0	1.3	0.1

Unused filter and pan (g)

5-Apr-01	1.56	1.57	1.56	1.6
26-Jun-01	1.58	1.58	1.58	1.6

Volume filtered (ml)

5-Apr-01	785	330	1000	650
26-Jun-01	750	500	700	800

Used filter and pan (g)

5-Apr-01	1.58	1.58	1.56	1.6
26-Jun-01	1.58	1.59	1.58	1.6